Apply Option-thinking in Long Term Infrastructure Investment: The Case of Commercial Real Estate

by

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ABSTRACT

Over the last two decades the application of real options theory has dramatically altered the way researches model infrastructure investment decisions. Real options are the right, but not obligation to do something for a certain cost within or at a specific period of time. Compared to the rich literature, its implementation in practice is however limited. This thesis identifies a common but ignored problem of the option valuation methodology. While trends and volatilities of market-based uncertainties are fundamental inputs for options valuation, they are in many cases difficult to get reliable estimates due to the changing patterns of the uncertainty factors. Current research on option valuation typically extracts estimates from data of a certain period (such as 10 years) without verifying the chosen period is superior to others. This thesis demonstrates this problem by analyzing the prices indices of underlying assets in real estate markets of U.S. and Singapore; and then shows how to adjust the flexibility design and valuation in long-term infrastructure development to capture the value of embedded options.

Since uncertainty is the key driver of option value, the study of uncertainty itself should always be at the core of flexibility design. An in-depth study of (a) both the feature/nature of each uncertainty (b) and interactions among different uncertainties, inside and outside of the project/investment is essential and extremely important to give rise to attractive real options. This thesis looks at a sub-part of long-term infrastructure development – commercial real estate – which is usually high-rise building existing in a highly volatile market. An option-thinking approach is proposed to guide flexibility design, both inactive and proactive flexibility. Proactive flexibility gives rise to an infrastructure design that makes sense for both now and the future. This happens when the design use uncertainties, not the requirements from the user meeting, as one of the primary drivers of the design. The approach involves three aspects: financial, technical and political. Particularly, the political aspect indicates that developers should carefully form contracts with partners/customers as well as relevant authorities to make it possible to exercise the options in the future when desirable.

This thesis uses a true case of mixed use commercial real estate development – Central in Singapore – to show the process of utilizing option-thinking in flexibility design and valuation.

**Thesis Supervisor: Professor Richard de Neufville
Professor of Engineering Systems & Civil and Environmental Engineering**

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Background

In 1973, Fischer Black and Myron Scholes established a model to price financial options (mainly the options of stock), which was later refined by Robert C. Merton and known as the Black-Scholes-Merton (BSM) formula. Merton and Scholes received the 1997 Nobel Prize of Economics for this and related work. This financial option-pricing model (Black and Sholes, 1973) focuses on factors affecting the value of the option over time and establishes a value for an option by assuming that a replicating portfolio of financial assets can be constructed to have the same return as the option in every state of the world (Amram and Kulatilaka, 1999).

In 1977, Stewart Myers pioneered the idea of viewing firm's discretionary future investment opportunities as real options – that is, the right but not obligation to undertake some business decision at a cost during a certain period of time. The term "real options" referred to the application of option pricing theory to the valuation of investments in non-financial or "real" assets where much of the value is attributable to flexibility and learning over time (Borison, 2005). A vast of literature has been developed, which elaborate both theoretical and empirical methods for quantifying the values of various real options (put or call option) to date.

In the 1980s and 1990s, Real Options Analysis (ROA) attracted moderate, primarily academic interest, most of which focused on real option valuation theory and its applications. Discounted Cash Flow (DCF) analysis was then (and also now) the traditional and widely used project valuation tool, but it is conceptually flawed due to the ignorance of value of flexibility and learning which makes it inadequate when a project will exist in an uncertain environment (de Neufville, 2003). And the ROA approach overcomes the flaws of DCF analysis mentioned above.

In the mid-1990s, research of real options valuation increased substantially and it also began to attract attention from industry as a potentially important tool for investment valuation and strategy. In application context, real options approach was primarily applied to decision-making elated to corporate investment projects and corporate valuation. The oil and gas industry was principally the first to apply real options analysis, then a range of other industries (mining, telecommunication, energy, R&D, infrastructure, manufacture, real estate and so on) and management consultants and internal analysts began to apply real options tools intermittently (Borison, 2005). It was also applied to system planning and design under uncertainty (de Neufville, 2003), supply chain management, et al.

Real options are recognized important in strategic and financial analysis because traditional valuation tools such as Net Present Value (NPV) ignore the value of flexibility. The option valuation recognizes the value of learning. This is important, because strategic decisions are rarely one-time events, particularly in investment-intensive industries. As suggested by Leslie and Michaels (1997), of the six variables in the real option valuation model, NPV analysis recognizes only two: the present value of expected future cash flows and the present value of fixed costs. The greater comprehensiveness of option valuation can therefore be summed up in this way: it captures NPV plus flexibility value – effectively, the expected value of the change of NPV over the option's life. Essentially, NPV can mislead whenever there is flexibility, especially flexibility to response to uncertainty over the rate of cash flow growth, because it incorporate only two key levers of value criteria (see Figure 1.1).

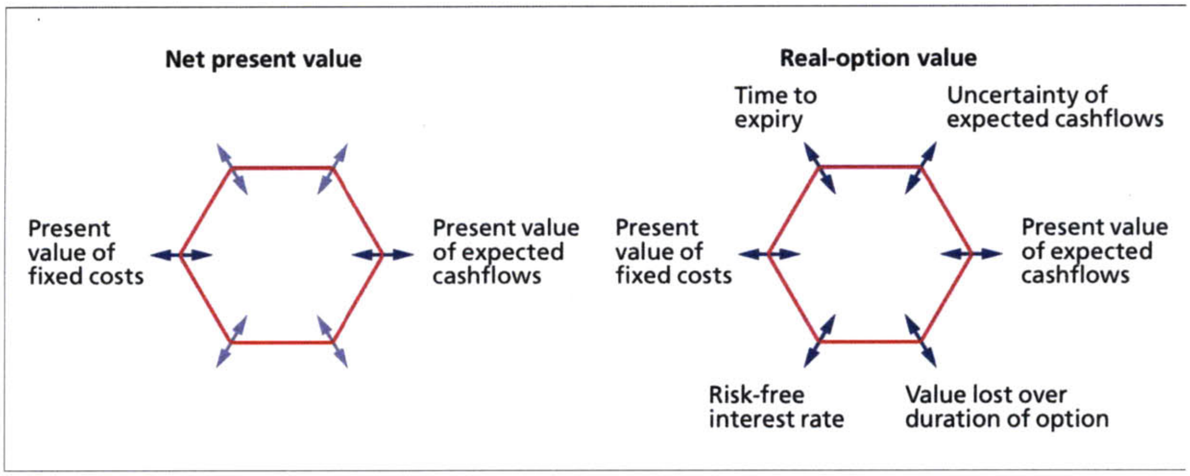


Figure 1.1: Comparison of Net Present Value and Real Option Value (Leslie and Michaels, 1997)

Copeland and Antikarov (2001) argued that NPV, the dominant approach for valuing investments, "systematically undervalues every investment opportunity" because of its failure to incorporate management flexibility. They argue that "real options will replace NPV as the central paradigm for investment decisions" within ten years. Clearly, these authors believed their approach to real options is applicable to every, or nearly every, major corporate investment decision where value maximization is the goal.

Real Options Analysis (ROA) is by now recognized as a most appropriate valuation technique for corporate investment decisions because of its distinctive ability to take into account management's flexibility to adapt ongoing projects in response to uncertain technical and/or market conditions. ROV has the potential to allow companies to examine programs of capital expenditures as multi-year investments, rather than as individual projects (Copeland, 2001). These programs of investments are typically strategic and highly dependent on market outcomes, a decision climate under which Miller and Park (2002) find ROV to be most useful. Luehrman (1998) discusses a variety of investments and approaches. He proposes that one class of investments, those he calls opportunities, should be approached using real options. These are staged investments where the initial investments typically do not provide cash flow but instead provides the right to make further investments.

1.2 Real Options in Real Estate Development

Over the last two decades the application of real options theory has dramatically altered the way researchers model real estate investment decisions. It has been applied to investigate various real estate problems including development (Titman, 1985) (William, Real Estate Development as an Option, 1991), re-development (Childs, 1996), abandonment of a property (Williams, 1991), lease contracts (McConnell and Schallheim, 1983) (Grenadier, 1995a), and mortgage default and refinancing decisions (Kau and Keenan, 1995), expansion of a property (de Neufville, 2003). It has also been used to explain the cyclical behavior of the real estate markets and prolonged periods of high vacancy rates (Grenadier, 1995b), the impact of regulatory taking policies on development decisions (Riddiough, 1997), the timing of conversion of agricultural/raw land into urban land (Capozza and Helsley, 1990), and the choice between long-term leases versus fee-simple leases (Capozza and Sick, 1991). Also, more specific real options in real estate development are proposed by the literature, for example, vertical phasing (Guma, 2008) (Pearson and Wittels, 2008), buy-back option in asset-backed securitization (Sing et al, 2003).

1.2.1 Category of Real Options in Real Estate

Real Options applied in real estate development are also called "real property options" by some researchers. Specifically, real property options are opportunities (and possibly implicit commitments) to acquire or develop or dispose of property (linked) real assets at an investment cost determined (or estimated) in the present with the benefits (future rents or property sales) delivered in the future (Patel et al, 2005). Real property call options are opportunities for the holder to benefit from the upside while only suffering the loss of premium (initial payment of the option, which equals "unrecoverable" initial costs for a real option) as a downside. Put options are opportunities for the holder to benefit from the downside, such as abandonment (recoverable salvage or distress sale value) or switch use possibilities. Written property put options may involve real or implicit warranties of resale values, firm commitments to build or value, which is the value of the option if it is exercised immediately, often referred to as the NPV of the investment.

There are many characteristic real property options, ranging from "vanilla" option models assuming a simple stochastic process, to combination or compound options, including complex stochastic processes, assuming uncertain cost and uncertain developed property values. Actually, real property options are among the earliest modeled real options, with now six primary practical uses (Patel et al, 2005): planning, investment timing, leasing, operations, funding and industry strategy, listed in following. Special real option considerations in real estate include the compound investment stages of research and preliminary planning and permitting, final permitting, grading infrastructure, and then building and letting.

- **Real property research and planning (R&D) options**
- **Property leasing options**

- **Property managing options**

  There are several operating options in managing properties, such as altering the tenant mix and configuration, the vacancy decision to avoid operating costs and also waiting to lock in higher rents, upgrading to meet changing tenant objectives, and the decisions regarding maintenance. Optimization of tenant mix may be an important strategy for the successful operation of a real estate project. In an environment with uncertain demand, the dynamic flexibility in adjusting the tenant mix adds value to a property.

- **Property funding options**

  Funding options should include any element of financing flexibility, such as the capacity to issue equity when the real option value of a quoted property company adjusted for other balance sheet items is less than the market capitalization, and repurchasing equity when the opposite holds. This would also cover restructuring and distress decisions. The most extensive and practical use of real options analysis is regarding the default and repayment options embedded in most real estate mortgage.

There are many different property-managing options (see Table 1.1). They are created and exercised at the discretion of managers. Managerial decisions are enabled and constrained by the resources and capabilities available to the organization, and learning occurs in sequential investment process as well as across investment projects. Real options concede management flexibility to act upon new information such that the upside economic potential is retained while the downside losses are contained.

Table 1.1: Real Managing Options Category

Option	*Description*	*Examples*
Defer	To wait before taking an action until more is known or timing is expected to be more favorable	When to develop
Expand or Contract	To increase/decrease the density in response to demand	Adding or subtracting space when tenants' business environment changes
Abandon	To discontinue an operation and liquidate the assets	Discontinuing a project
Stage Investment	To commit investment in stages giving rise to a series of valuations and abandonment options	Staging of development projects or financial commitments to a new venture
Switch Use	To alter the mix of space in response to market prices	Optimal space allocation between tenants
Grow	To expand the scope of activities to capitalize on new perceived opportunities	

1.2.2 Implementation of Real Options Analysis for Real Estate Development

In the case of real estate, a typical application of real options theory is the land development option, which can be seen as a call option. Samuelson (1965) with McKean (SM) developed an analytical solution for a perpetual American option (that can be exercised at any time). This is appropriate to value a perpetual opportunity to convert land into buildings.

Particularly, real options analysis in real estate is applied to the valuation of vacant land (Geltner, et al, 2007). Land value as a contingent option to purchase a number of different possible buildings at exercise prices equal to their construction costs. Owners of vacant land have options associated with the type of developments (office, retail, industrial, residential) subject to planning permission. Geltner et al (2007) point out a deeper and more fundamental application of real option theory to real estate is to apply the option model to the land itself, the asset that is characteristic of all real estate. And this is at the very heart of the real estate system because

Option Valuation Theory (OVT) can now shed light directly on the relation between land value and the timing and nature of the development of buildings on land. The application of real option theory to real estate is what may be termed the "call option model of land value". In this model, land is viewed as obtaining its value through the option it gives to its owner to develop a structure on it. The landowner obtains a valuable rent-paying asset upon the payment of the construction cost necessary to build the structure. More broadly, the landowner's option includes also the option to demolish and/or redevelop any existing structures on the land. The option model of land is therefore most applicable either to vacant land, or else to land in transition zones where the highest and best urban use of the land is changing. In any case, it is important to keep in mind that the real option is viewed as giving land its value is essentially the land development option.

The reason that the call option model of land value can have such a fundamental and central place in furthering our understanding of real estate system is that it relates directly to some crucial links in the big picture of the real estate system. Land is the characteristic component that distinguishes real estate from other types of assets. The call option model allows us to better understand and quantify the land value. Real option theory shed light on the important link between land value and real estate development (Geltner et al., 2007).

One of the important differences between real and financial options is the ability to vary the capital intensity of the investment, i.e., the capacity or output level. The capital intensity of a project is important when there is a fixed factor like land or labor. Analytically, the ability to vary capital intensity means that the exercise price of the option is endogenous rather than fixed. The most common application of options with an endogenous exercise price is to real estate development. Capozza and Li (2001) extend the real option model of urban land conversion by allowing variable capital intensity in land development.

The optimal timing of development options is extremely important and attracts many researchers' attention. The value of the undeveloped property depends upon not only the operating revenues from the developed property but also its costs of development, both of which can evolve stochastically over time. Compared to problems with financial options, the real estate owner's options are more complex and are driven by a different set of stochastic state variables. Williams (1991) computes the optimal exercise policies both analytically and numerically for the options to develop or to abandon real estate.

For traditional financial options, optimal exercise strategies can be derived without consideration of strategic interactions across option holders (Grenadier, 1996). However this is not true regarding real options exercise in real estate. The assumption that firms have exclusive and monopolistic access to investment opportunities and thus can exercise development options as an independent event is not realistic in a competitive real estate market (Chu and Sing, 2007). Strategic interaction has been incorporated in the modeling of optimal timing decision for real estate development projects. Grenadier (1996) develops a duopoly model with strategic interaction that explains irrational overbuilding and recession induced construction boom occur in a declining market. In his model, there are two developers and they are symmetric and indifferent of the roles of a leader and a follower. William (1993), Wang and Zhou (2006) also attempted to integrate game theoretic feature into real estate option models. Chu and Sing (2007) extend Grenadier's model by allowing the two developers to have asymmetric demand functions in order to examine the relative strength of the two developers and their effects on optimal timing in equilibrium. Specifically, they propose a duopoly optimal development timing model with two independent demand curves to stimulate asymmetric price effects on the sub-game equilibrium strategies of the developers. Besides, Cunningham (2007) examines the effect of price volatility - a generator of option value - on the timing of development.

Barthelemy and Prigent (2009) show that the real estate investor may choose the optimal time to sell the property according to market fluctuations and information from past observations. In this situation, the investor actually faces an "American" option problem. They prove that real estate portfolio value strongly depends on the optimal time to sell and analyze three such optimal times: the first one implicitly assumes that the investor can only choose the optimal time to sell at the initial date, but this kind of solution is not time consistent since the same computation of optimal time to sell at a future data leads to a different solution; the second one corresponds to a perfectly informed investor, which is not too realistic; the third one used the American option framework and is more "rational" by taking account of intertemporal management and cumulative information, this approach can reinforce the property value both when the volatility and the maturity are increasing.

Real estate construction is an important class of irreversible investments and real options models can prescribe rules for the optimal timing of making irreversible investments. The real option rules for the optimal timing of irreversible real estate investment can be prescribed in terms of a hurdle rent. Fu and Jennen (2009) find that the volatility not only directly raises the hurdle rent and hence delays new construction but also influences how investment decisions respond to the real interest rate growth expectations. That is the effect of the interest rate and growth expectation on the hurdle rent becomes more negative when the volatility is greater, as predicted by the real option model. Extant real option models generally assume a constant risk premium. They show that anticipated changes in the risk premium could influence the timing of irreversible investments.

Fu and Jennen (2009) also argue that it is a myopic approach to construct the measures of expected demand growth and volatility based on past growth rates. Holland et al. (2000) represents an exception in that they use a forward-looking implied volatility measure derived from commercial real estate debt prices. Reliable prediction of building activities based on real option models require forward-looking measures of demand growth expectations. Yu and Jennen derive such a measure from the forward-looking behavior of local asset prices. Specifically, they take advantage of the active stock market in Singapore and Hong Kong to construct several forward-looking variables for empirical test of the real option model. These termed stock-market-based forward-looking variables include: (1) volatility or total risk, (2) risk premium for systematic risk, (3) demand growth expectations, and (4) premium expectations.

Through in-depth case studies of four major projects in North America, Guma et al (2009) demonstrate that significant vertical phasing – that is, the addition of five or more stories to an existing building – has significant organizational and logistical advantage for corporate developers and thus is a valuable real option on a strategic level. They also show that vertical phasing is both attractive and feasible for flexible development of real estate in a risky environment, which has not drawn the industry's attention.

Lentz and Tse (1995) use option pricing to examine how the presence of hazardous materials affects real estate value. The owner has two options: the first is to remove the hazardous materials at the best time; the second, embedded in the first, is to redevelop the property at the best opportunity. And the owner has three possible timing strategies to exercise these two options: remove the hazardous materials first and retain the option to redevelop the property later; remove and redevelop at the same time; or do nothing. They also analyze the influence of the regulatory environment with respect to the option exercise timing strategies.

Property development activities are appropriately modeled as sequential American exchange property options (SAEPO) since they always occur in stages and there is interim expenditure required to keep the property development options "alive" (Paxson, Sequential American Exchange Propety Options, 2007). Paxson points out that decontaminating and developing "brownfield" sites are real sequential compound exchange activities consist of at least two phases: first phase of decontamination expenditure (D) and second phase of construction (K). Project managers have the choice of timing of the phases – the management flexibility – given the expected property value (V). Besides brownsite development, other possible applications of the SAEPO model include residential building replacements in low density, low quality housing areas, commercial property leases and rural property alternatives. They present a closed-form solution for SAEPO.

Paxson (2005) addressed that the principle that the optimal investment strategy for a property owner should reflect the expected variability of future profits and current profits relative to thresholds for a variety of states and actions including remaining idle, building and operating properties, expanding, contracting, suspending, reverting to normal service or reduced service capacity, or abandoning. Paxson concluded that triggers for these different options depend on the number and type of feasible options, and on the relationships among the alternatives (Figure 1.2).

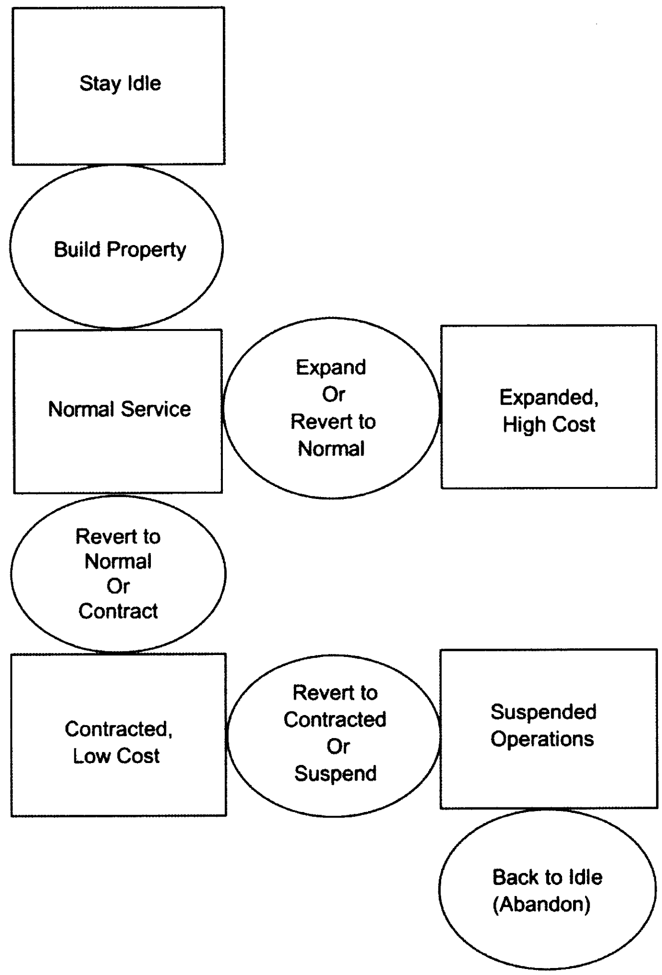


Figure 1.2: Property states and actions (Paxson, 2005)

The phenomenon that the long-term decline in the number of transactions and liquidity of real estate that frequently follow negative demand shocks does not have satisfying explanation. Cauley and Pavlov (2002) estimated the option-like value of an owner's interest in a property in a specific market – Los Angeles single-family dwellings, and found that when an owner has little or negative equity, the value of waiting to sell is likely to exceed the net carrying cost. Thus the option value of a potential seller's interest may eliminate the possibility of an otherwise mutually advantageous transaction, which Cauley and Pavlov believed could be part of the explanation for the asymmetric response of real estate markets to positive and negative demand shocks.

Grenadier (1995c) uses the methods of option pricing theory to derive and analyze the intertemporally optimal tenant mix policy, which is one of the critical determinants of success in real estate projects. Specifically, in Grenadier's model, tenant types are broadly defined to include not only the standard distinctions (office, retail, industrial, residential), but also more subtle distinctions such as the nature of business, preferences, or degree of credit risk. He decomposes the value of the optimal mix strategy into two kinds of flexibilities: dynamic flexibility emanating from the sequence of underlying leasing options and static flexibility resulting from the ability to determine an initially optimal portfolio of tenant types.

The option-based pricing model provides a tool for evaluating mortgage instruments by considering the probable cash flow across a range of possible future economic scenarios. Carron and Hogan (1988) show this model indicate relative value in the mortgage market, provide duration estimates useful for hedging purposes. They also address its pitfalls including excessive reliance on the results as indications of absolute value, failure to realize the presumption that option-adjusted spreads represent a guaranteed or arbitragable return.

Buy-back option is a unique feature embedded in the asset-backed securitization (ABS) in Singapore, which allow the originator to retain a contingent claim on the upside potential of the asset price. Sing et al. (2003) estimated the price of such buy-back options embedded in the ABS contracts using the multi-period binomial option pricing framework proposed by Cox et al. (1979).

Although more and more fine sorted options are developed by the literature, this approach has not been widely adopted by the management professionals in real estate development. We will discuss the potential barriers for the application in the next section and especially introduce the engineering-based approach, which is designed to overcome the barriers.

1.3 Real Options Valuation Approaches

Real Options Valuation Theory in General

Although there is great deal of agreement about the appeal f the underlying concepts, a variety of option valuation approaches have been suggested for implementing real options in practice. There are mainly four approaches: (1) Black-Scholes-Merton (BSM) Formulas, (2) Decision

Analysis, (3) Dynamic Programming, and (4) Monte Carlo Simulation. Adam Borison pointed out that (2005), "The assumptions underlying these different approaches and conditions that are appropriate for their application are typically not spelled out". As a result, this situation leaves the potential practitioners in troubling circumstances since they may choose an inappropriate model or use the model inappropriately in practice.

For a given situation, knowing which method to apply is as important as the method itself. Borison (2005) contrasted major real options valuation approaches based on three fundamental issues:

- Applicability: what does the calculated real option value represent, and when is it appropriate to use this calculation?
- Assumptions: when applied appropriately, what are the notable assumptions underlying the approach, and what is the evidence regarding the validity of these assumptions?
- Mechanics: provided the assumptions are valid, what steps are involved in applying the approach, and what are the associated difficulties?

Based on three perspectives, Borison (2005) divided the approaches into five groups:

(1) The classic approach (no arbitrage, market data): it refers to the direct application of classic option pricing from finance theory (BSM formula) to nonfinancial or real asset investments.
(2) The subjective approach (no arbitrage, subjective data): this approach takes a half-way from the classic approach – it is also based on replicating portfolio/no-arbitrage arguments and the use of standard option pricing from finance, but in the place of the explicit identification of a replicating portfolio, this approach uses entirely subjective estimates of inputs. This approach is explained in details by Timothy Luehrman (1995) in "Investment opportunities as real options: getting started on the numbers".
(3) The Market Asset Disclaimer (MAD) approach (equilibrium-based, subjective data): This subjective approach takes a full step away from the classic approach. It does not reply on the existence of the replicating portfolio and use subjective assessed inputs data for

valuation calculation. Representative work is in Tom Copeland and Vladimir's (2001) book "Real options: a practitioner's guide".

(4) The revised classic approach: This approach revised the classic one based on the view that there are two different types corporate investments – investments dominated by market-priced /public risks and investments dominated by corporate-specific/private risks – each requiring its own approach. The classic finance-based real options analysis should be used when investments are dominated by market-priced/public risks, and management science-based dynamic programming/decision analysis should be applied when investments are dominated by corporate-specific/private risks.

(5) The integrated approach: Like the revised classic approach, it also acknowledges that there are two types of risk associated with most corporate investments: public/market and private/corporate. But instead of separating the investments into types, it acknowledges that most realistic problems have both kinds of risk and is designed to address that situation.

The classic and subjective approaches are based on fairly no arbitrage assumptions, but leave unsaid what to do when those assumptions do no apply. The MAD approach, on the other hand, states very explicitly that the assumptions are not restrictive, and that real options can be applied to all corporate investments, irrespective of the existence of a replicating portfolio. In contrast, the revised classic approach states explicitly that the assumptions underlying real options are restrictive. They suggest that the classic finance-based real options approach can be applied where these assumptions apply, and that management science-based approach such as dynamic programming and decision analysis can be applied where they do not. The primary, conceptual difficulty with the revised approach is separating all investments, in various shades of grey, into black and white, namely "all-market risk" and "all private risk". Once this separation is achieved, then the difficulties faced are those of the classic approach in one case and those of standard decision analysis in the other. In the latter, the major problem is developing calibrated subjective inputs from experts. Also, there is the added complication of interpreting decision analysis results in shareholder value terms.

This paper supports the view of the integrated approach compared to other approaches stated above. Like several of the approaches mentioned above, the integrated approach acknowledges that there are two types of risk associated with most corporate investments: public/market and private/corporate. However, rather viewing private risk as a source of error as in the classic approach or forcing investments entirely into one category or the other, the integrated approach acknowledges that most realistic problems have both kinds of risk and is designed to address that situation. This approach was first described in depth in Smith and Nau (1995) and in Smith and McCardle (1998), although the authors specially refer to their approach as the integration of option pricing and decision analysis not as a real option. Given its origin in management science rather than finance, the integrated approach is based on a somewhat different philosophy than other approaches. This approach recognizes that firms have a variety of stakeholders, owners and managers in particular. It then establishes a goal of making investment (and financing) decisions to maximizing the utility of these owners and managers. The approach is to "mark to market" the option of value of any asset driven by public risks, and to rely on judgment for the portion of value of any asset driven by private risks. The integrated approach appears to be the only one takes the view that corporate investments typically involves a mix of public and private risks, and that an accurate valuation depends on addressing both.

Valuation of Real Property Options

Since this thesis focuses on the application of real options in long-term infrastructure investment, we specifically review the valuation of real property options.

There is a rich literature on modeling real property options and some assumptions are general across many models. Most authors assume that the "underlying" eventual property value is (or can be valued like) a perpetuity, although some assume a finite life (or sale) for the project. Most authors assume the "underlying" eventual property value volatility is constant or deterministic over time, and that there is a constant (sometimes risk-adjusted) property value escalation over time. They also assume there is instantaneous development expenditure, but some assume stages of expenditures and/or time-to-build. A few authors assume that there are property innovators (first movers) who are influenced by attitudes towards risk and growth and the action of other competitors.

The traditional NPV approach ignores managerial flexibility and real options embedded in projects. Flexibility is desirable if there is uncertainty in the future usage of the building. The uncertainty can be due to tenant needs, market conditions, competitive scenario, corporate strategy, and economic and regulatory policies among other factors. By incorporating real options properly into the property development, uncertainty can become our ally, not enemy. Besides, the attractiveness of real options analysis in real estate, there are several potential barriers to its Implementation in this industry. A simple and transparent real options valuation tool interests most real estate developers considering the complexity of current real options valuation methodologies. Another challenge is whether the nature of the uncertainty (measured by volatility) built into model can reflect the reality. If not, many developers would mistrust the results from the model. The potential barriers are the main reasons that prevent the application of ROA to value real estate development. The engineering-based approach, first presented by de Neufville et al. (2006), is designed to over these barriers.

Table 1.2: Merits and Demerits of Economic-Based Approach and Engineering-Based Approach (Masunaga, 2007)

	Economic-based approach	*Engineering-based approach*
Merits	It can calculate the "true" real options price under the market equilibrium theory.	(1) The user does not need to understand advanced financial theory (2) The analysis can be done with normal computational resources. (3) It has many ways to present the result graphically.
Demerits	The user needs to understand the financial theory of real options.	It is not always possible to calculate "true" real options value, mainly due to the arbitrary assumptions of single risk-adjusted discount rate.

The real options model presented by Barman and Nash (2007) is a hybrid of the economic and engineering real options methodologies. On the one hand, their decision rules are based on the traditional NPV metric and the Samuelson Mc Kean (S-M) hurdle value, and they also use the S-M formula to calculate the abandonment value of land. On the other hand, the broad framework of their model is based on the so-termed engineering approach. They use Monte Carlo simulations to incorporate uncertainty and employ the performance metrics including Expected Net Present Value (ENPV) and Value at Risk and Gain (VARG) curve. This model addresses three commonly-faced scenarios in real estate developments:

- When and how to phase a project instead of building it all at once;
- The valuation of various development programs under uncertainty;
- Valuation of the option to defer a development project in suboptimal market conditions.

From the eighteen semi-constructed interviews with real estate professionals they conducted, they found that static measures such as "return on cost" or "development yield" (obtained by dividing the projected stabilized net operating income (NOI) by the total cost of the project), are widely used though they are simple. And developers value real options indirectly in two ways (Barman and Nash): by adjusting the project values of assumed risk and return and by performing sensitivity analysis for key uncertain variables associated with a given project. Such hybrid model may be a better alternative for the developers to value real options without requirement of advanced finance theory.

1.4 Problem statement

Although the inability of traditional NPV analysis to capture the value of flexibility has already been well explained by many researchers and the rich literature on real options analysis, NPV analysis is still considered as the normative approach in various industries.

- In 2000, Bain and Company conducted a survey of 451 senior executives covering 30 industries regarding their views of management techniques, and only 9% reported using real options (Teach, 2003).
- In 2002, Ryan and Ryan's survey of 208 CFOs found real options trailing the list of 13 supplementary capital budgeting techniques with a utilization rate of 11.4%, while 85.1% of the respondents used sensitivity analysis and 96% used traditional NPV analysis for basic capital budgeting (Block, 2007).

- Block (2007) surveyed Fortune 1,000 companies to see if they have picked up on the use of real options to complement traditional analysis. Out of 279 respondents, 40 were currently using real options (14.3%). The reasons why the rest resisted using real options analysis they identified in the survey are listed in Table 2.

Table 1.3: Reasons for Not Using Real Options Analysis (Block, 2007)

Reasons	**Percentage (out of 239 firms that not using real options)**
Lack of top management support	42.7%
Discounted cash flow is a proven method	25.6%
Requires too much sophistication	19.5%
Encourage too much risk taking	12.2%
	100%

- As for the number one reason for not using real options, lack of top management support, Block (2007) pointed out that "further comments indicated that the top managers of many companies are hesitant to accept a methodology they cannot follow step by step and many felt that top management was turning decision-making over to mathematicians and decision scientists, and they were being taken out of the loop".
- The second reason given is DCF is a proven method and thus a preferred one. According to Block's survey (2007), downplay methods such as the payback period, the average rate of return, NPV and IRR, are the typical procedure.
- The third reason is the sophistication of real options analysis. Block argued that the comparably great "application of real options in technology, energy, utilities, etc, is consistent with the fact that top management in those industries often having engineering or technology background", while managers in industries such as retailing, food processing and etc. do not.
- The fourth reason given here is the results from real options analysis tend to encourage excessive risk-taking. Based on the conversation with top executives, van Putten and MacMillian (2004) stated that "CFOs tell us that real options overestimate the value of

uncertain projects, encouraging companies to over-invest in them. In the worst case, they grant excessively ambitious managers a license to gamble with shareholders' money".

Based on the review of the reasons for not using real options discussed above, Block (2007) argued that this resistance could be associated with academia's lack of understanding of the incentive effects of real options on institutional decisions. It is clearly important to identify the barriers from the top managers' angle besides from the academia's, in order to widen the application of real options in practice. The engineering-based approach, first presented by de Neufville et al. (2006), is designed to overcome the barriers stated by reason one and three. For the fourth reason, real options analysis is not try to encourage the managers to make decisions that have more risks, but to make use of uncertainty or at least deal with uncertainty. "Take advantage of uncertainty" definitely does not equal "take more risk" but "use real options to effectively hedge the risks". Further research and effort should be made to bridge this gap of concept of real options between the academia and the practitioners.

1.5 Roadmap

This thesis addresses this problem by building upon the work of other scholars and deploying original analysis to add value to the discussion.

After the introduction in Chapter 1, Chapter 2 identifies a common problem of real option valuation and explains it using the commercial real estate markets in U.S. and Singapore.

Chapter 3 firstly discusses how to apply option-thinking to guide flexibility design in long-term infrastructure investment and adjust the real options valuation methodology to deal with the issue identified in Chapter 2. This chapter focuses on uncertainty itself, which is the key driver of option value. This chapter proposes to design flexibility by considering the interactions between different uncertainties involved in a project. This chapter addresses the role of competition in real options analysis. A framework of applying real options analysis summarizes the key steps from operational perspective.

Chapter 4 applied the methods of Chapter 3 to real world case study – a mix use commercial real estate development based in Singapore.

Chapter 5 addresses the policy perspective of designing and exercising real options in practice.

Chapter 6 concludes the entire discussion with a concise summary of the previous chapters and several conclusions. Recommendations are then given as to how apply option-thinking to improve decision-making in long-term infrastructure investment.

CHAPTER 2: DIFFICULTY IN IDENTITIFYING TRENDS AND VOLATILITIES OF PROPERTY PRICE INDICES

The trends and volatilities of market prices are fundamental inputs for the valuation of real options, which are in many cases difficult to get meaningful estimates. However, because of the changing patterns of the prices for the underlying assets, the estimates of their trend and volatility are highly sensitive to the span of time being considered. Current research on option valuation methodologies typically extracts estimates from data of a certain period (such as 10 years) without verifying that this period used is superior to others. This thesis investigates the sensitivity of price indices to the span of time considered. To do so, it takes the U.S. ands Singapore real estate markets as examples.

2.1 The U.S. Real Estate Market

There are different property price indices for the U.S. market, such as NCREIF (National Council of Real Estate Investment Fiduciaries) Property Index and the Transaction Based Index (TBI) developed by the MIT Center for Real Estate (CRE). This analysis uses the Transaction Based Index (TBI) because it spans a long enough period.

As described by the CRE, "The MIT/CRE CREDL Initiative has developed a Transactions-Based Index (TBI) of Institutional Commercial Property Investment Performance. The purpose of this index is to measure market movements and returns on investment based on transaction prices of properties sold from the NCREIF Index database. This is a new type of index that offers advantages for some purposes over the median-price or appraisal-based indexes previously available for commercial real estate in the U.S. Median price indexes are not true price-change indexes because the properties that transact in one period are different from those that transacted in the previous period. Appraisal-based indexes are based on appraisal estimates rather than actual prices of actual transactions." (MIT CRE, http://web.mit.edu/cre/research/credl/tbi.html)

Transactions-based indices often provide a more up-to-date or precise picture of movements in the real estate market than these other types of indices. The MIT Center for Real Estate is providing the TBI for research purposes as a service to the industry and academic research communities. Fisher, Geltner & Pollakowski (2007) describe the TBI methodology in detail.

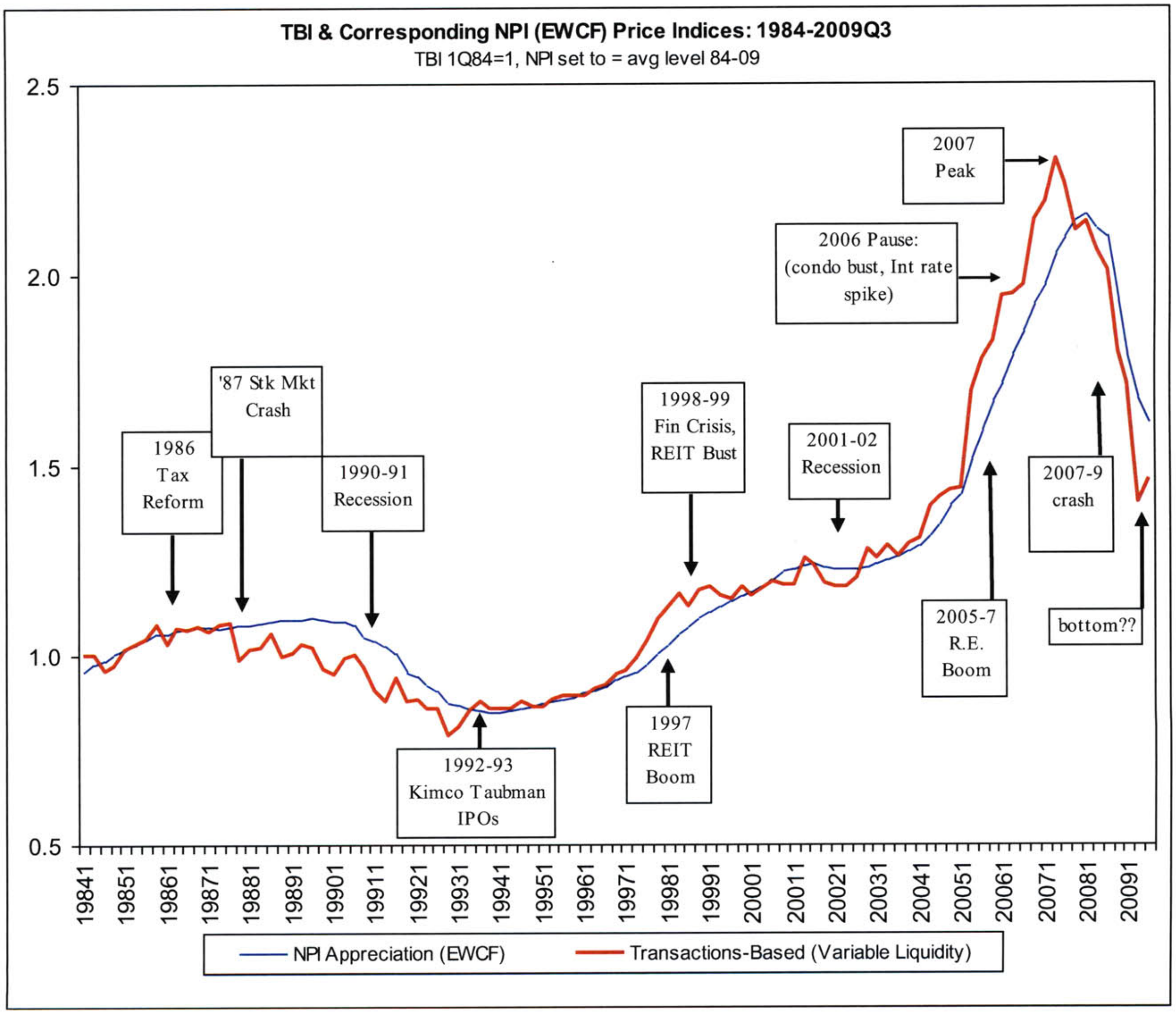
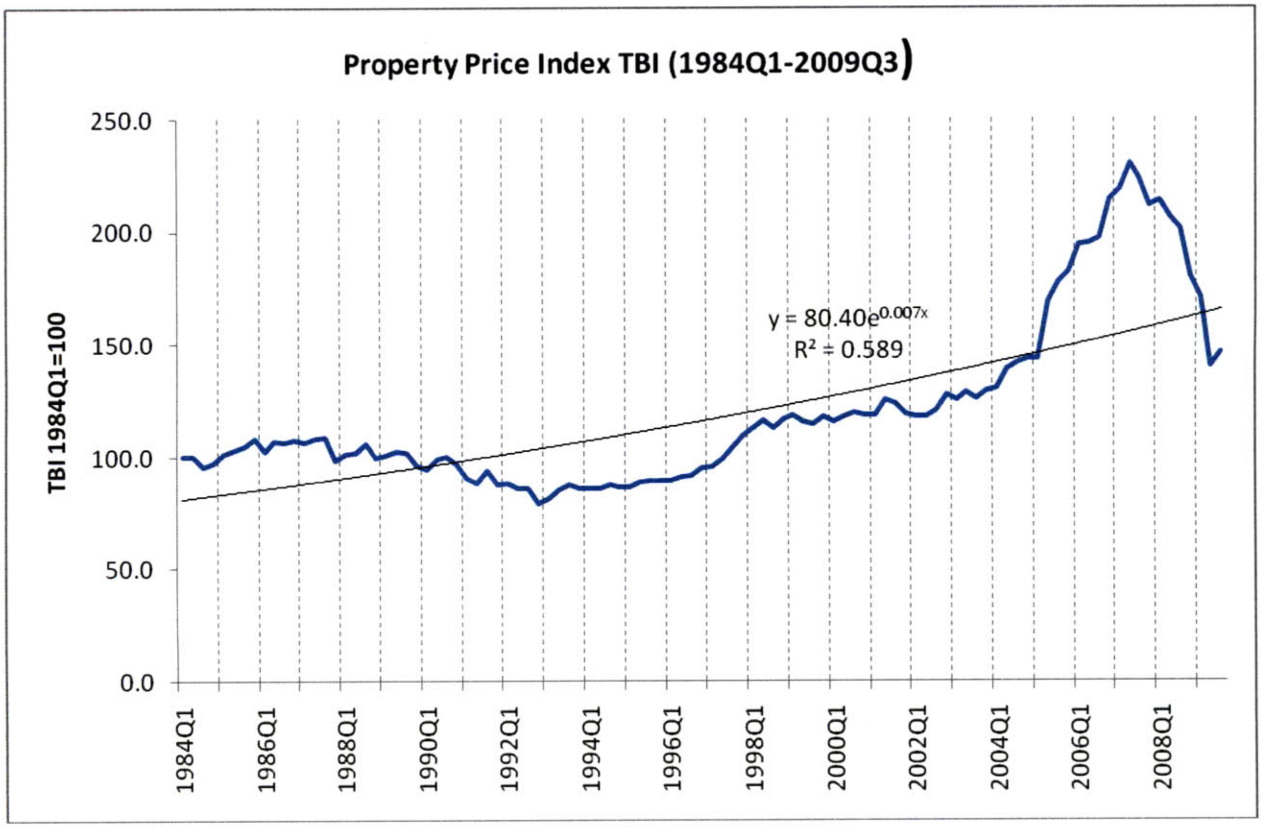


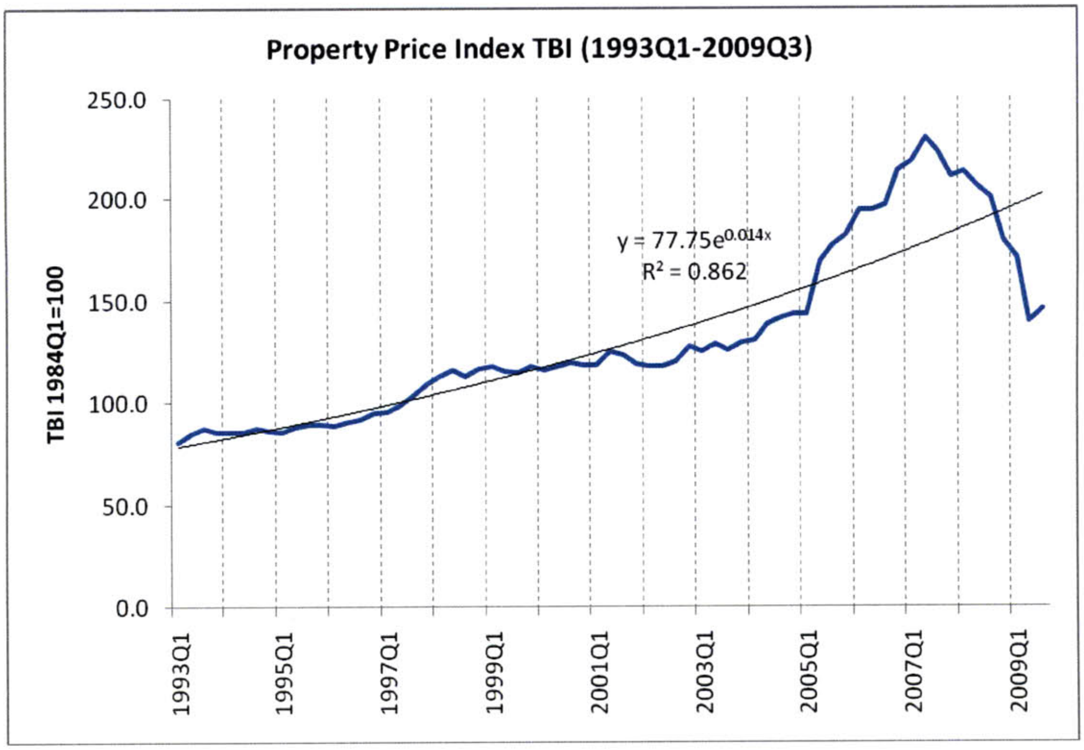
Figure 2.1: TBI and corresponding NPI Price Indices 1984Q1-2009Q3 (Source: MIT CRE)

We use the TBI to illustrate why it is difficult and ambiguous to identify the potential property price trends and volatilities based on the historical data series. The basic problem is that we can get very different estimates of price index trends and volatilities depending on the time span of the data series we choose to do the calculation.

(a)


Property Price Index TBI (1984Q1-2009Q3)
250.0
200.0
150.0
100.0
50.0
0.0
TBI 1984Q1=100
y = 80.40e^0.007x
R² = 0.589
1984Q1
1986Q1
1988Q1
1990Q1
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
2006Q1
2008Q1

(b)



(c)

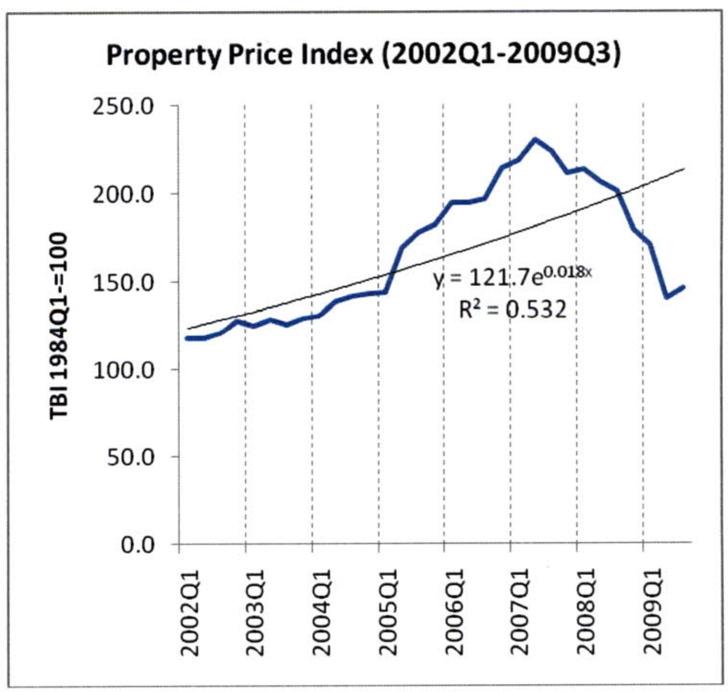


Figure 2.2: Property Price Index (TBI) of different periods

Table 2.1: Trends Calculated Based on Different Data Series

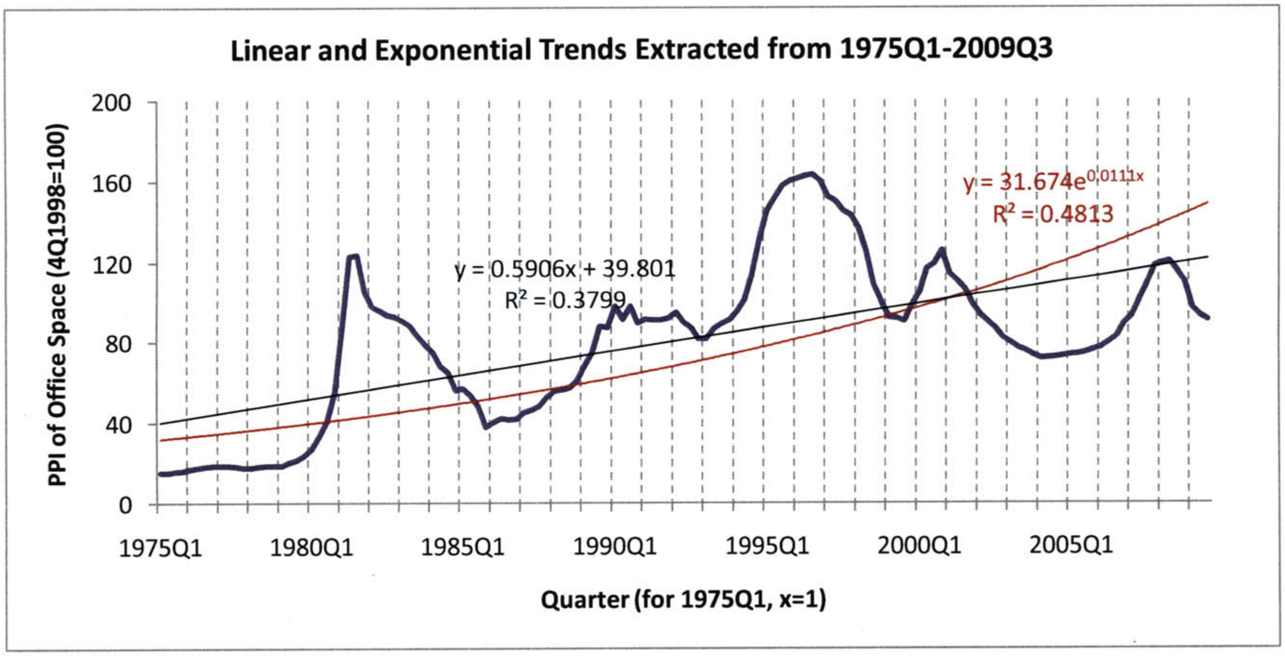
Data Series	Quarterly Growth Rate (%)	Annual Growth Rate (%)
1984Q1-2009Q3	0.70	2.84
1993Q1-2009Q3	1.43	5.76
2002Q1-2009Q3	1.81	7.47

2.2 The Singapore Real Estate Market

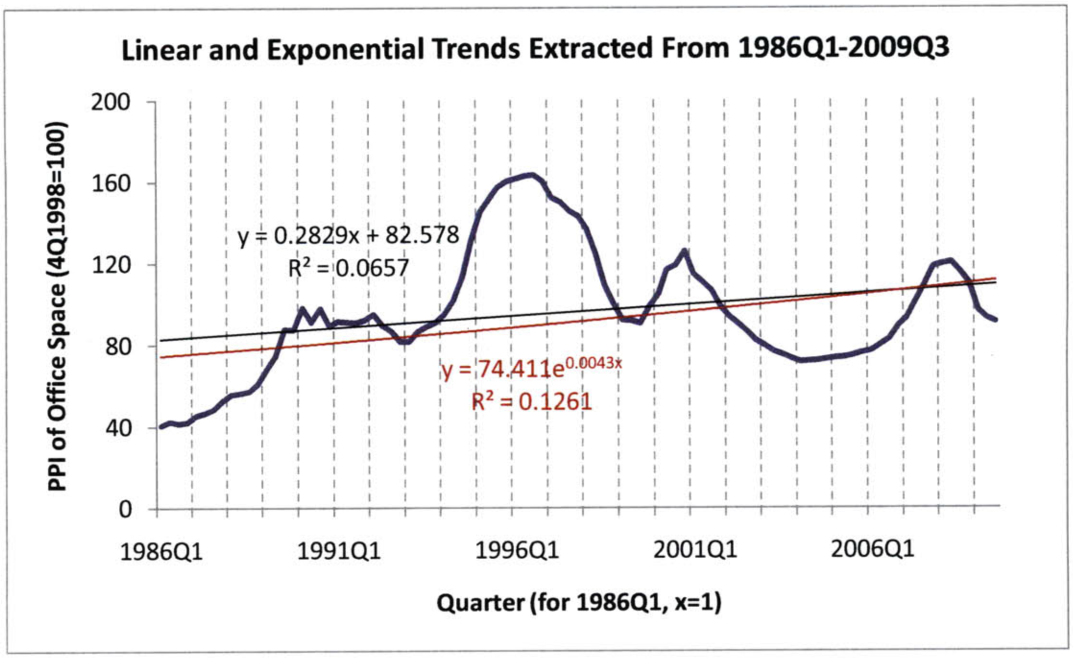
A similar analysis for Singapore demonstrates the same issue. In this case, the analysis uses the property price index from Urban Redevelopment Authority (URA) of Singapore. In this case:

- The prices in 4Q1998 provide the base index of a value of 100.
- The indices are compiled based on a moving average weight method, using the value of transactions in the past 12 quarters as weights.

(a)

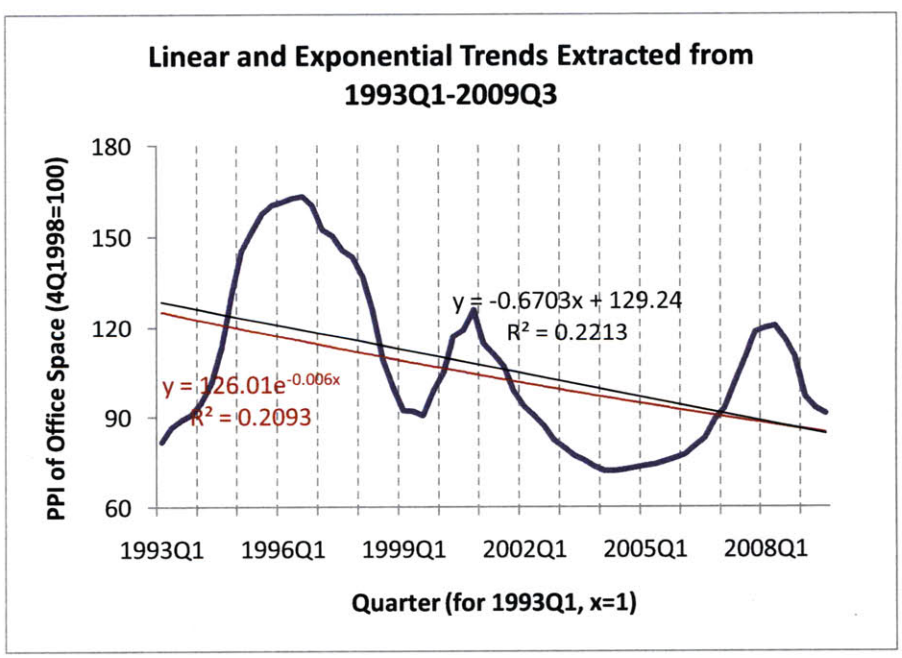


(b)



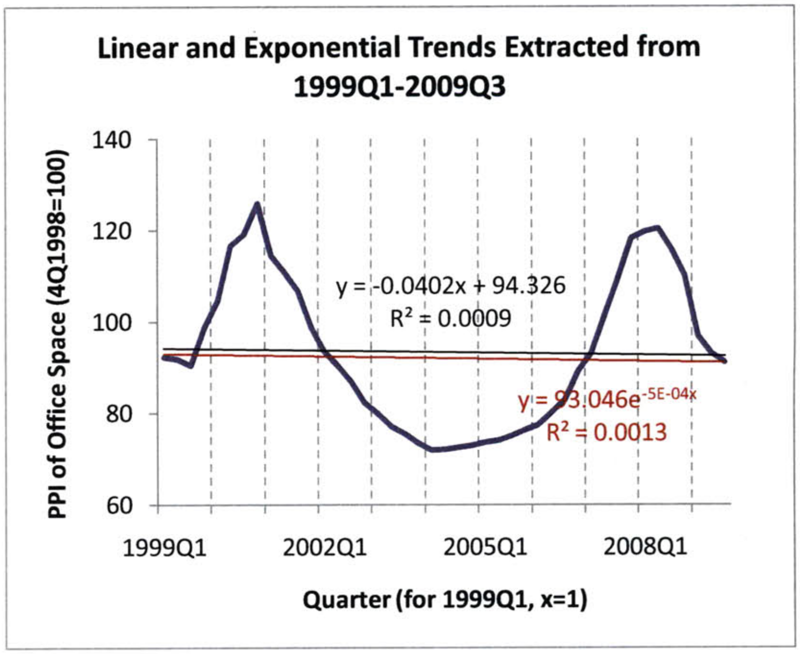
Linear and Exponential Trends Extracted From 1986Q1-2009Q3
PPI of Office Space (4Q1998=100)
200
160
120
80
40
0
y = 0.2829x + 82.578
R² = 0.0657
y = 74.411e^0.0043x
R² = 0.1261
1986Q1
1991Q1
1996Q1
2001Q1
2006Q1
Quarter (for 1986Q1, x=1)

(c)



Linear and Exponential Trends Extracted from 1993Q1-2009Q3
PPI of Office Space (4Q1998=100)
180
150
120
90
60
y = -0.6703x + 129.24
R² = 0.2213
y = 126.01e^-0.006x
R² = 0.2093
1993Q1
1996Q1
1999Q1
2002Q1
2005Q1
2008Q1
Quarter (for 1993Q1, x=1)

(d)



(e)

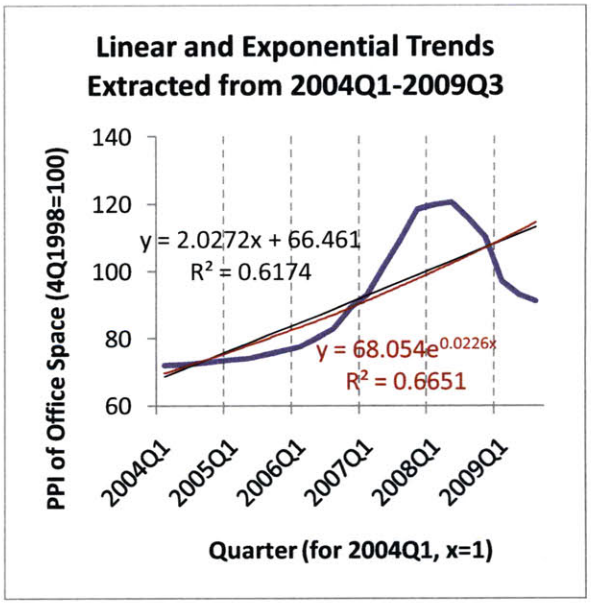


Figure 2.3: Different trends extracted from Singapore office space price index based on different periods

Table 2.2: Exponential Trends and Volatilities Extracted From Different Data Series

Time Series	Quarterly Growth Rate (%)	Annual Growth Rate (%)	Standard Deviation(%)
1975-2009	1.111	4.544	50.730
1986-2009	0.426	1.719	32.426
1993-2009	-0.590	-2.332	22.963
1999-2009	-0.005	-0.020	18.201
2004-2009	2.259	9.457	11.214

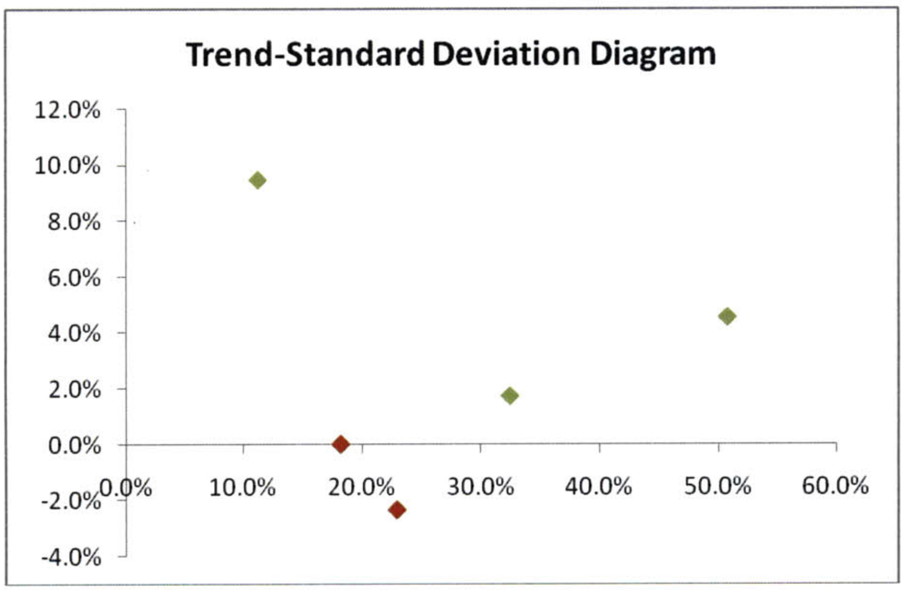
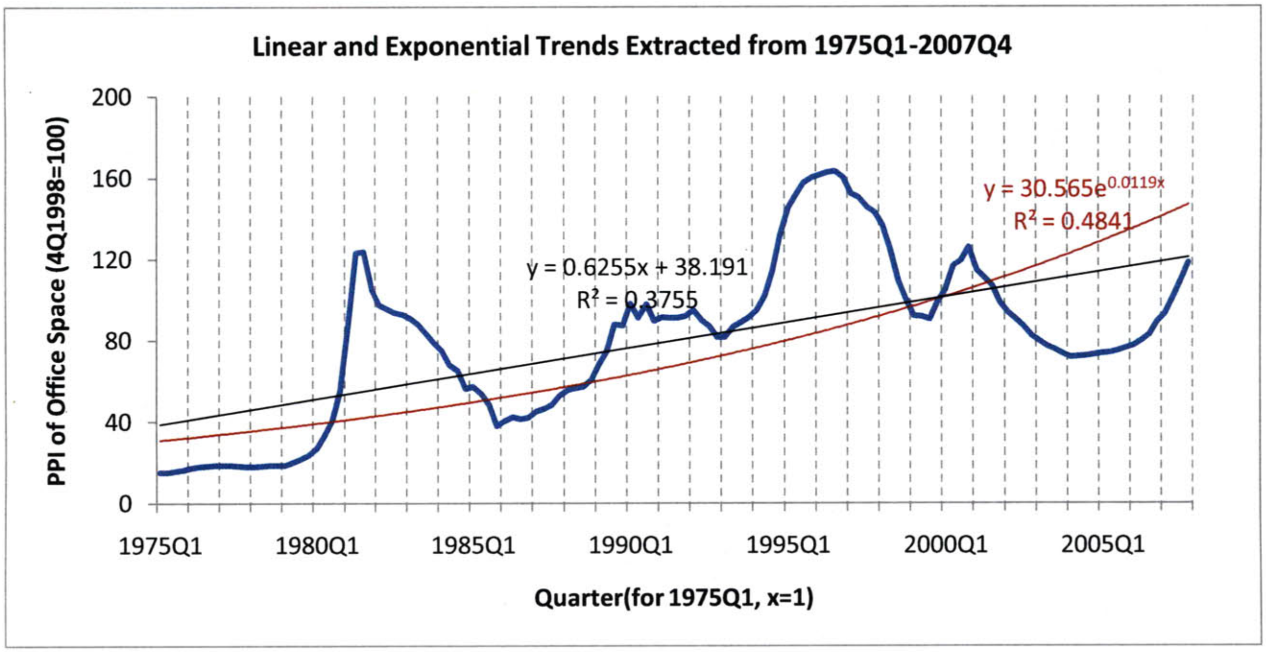


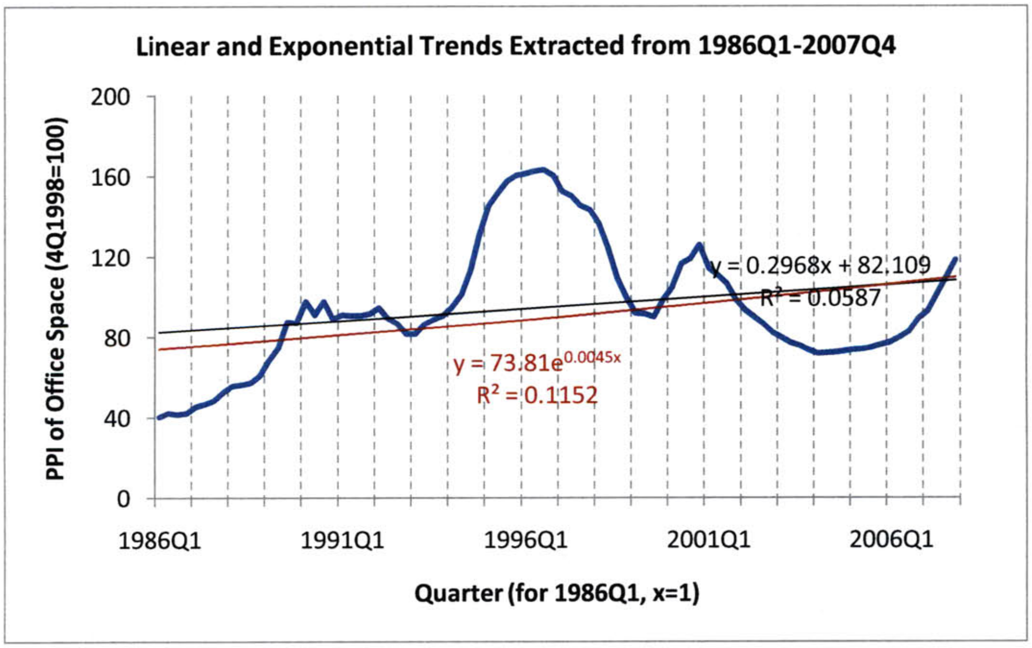
Figure 2.4: Trend-Standard Deviation Diagram (Trends – Annual Growth Rate)

Judging from Figures 2.3 (a, b, c, d and e), there is a clear downward trend starting from the 3rd quarter of 2008 due to the global financial crisis. Actually, suppose we are now standing at the beginning of 2008, we recalculate the trends and volatilities of the office price index; and we can get a very different set of corresponding trends and volatilities, although we only ignore the data in 2008 and 2009.

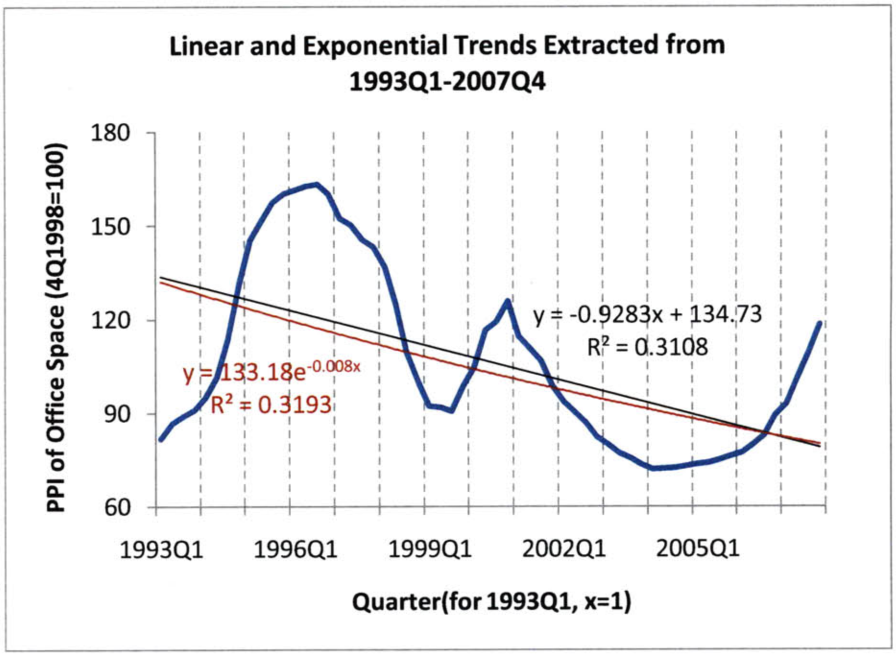
(a)


Linear and Exponential Trends Extracted from 1975Q1-2007Q4
PPI of Office Space (4Q1998=100)
200
160
120
80
40
0
1975Q1
1980Q1
1985Q1
1990Q1
1995Q1
2000Q1
2005Q1
Quarter(for 1975Q1, x=1)
y = 0.6255x + 38.191
R² = 0.3755
y = 30.565e^0.0119x
R² = 0.4841

(b)

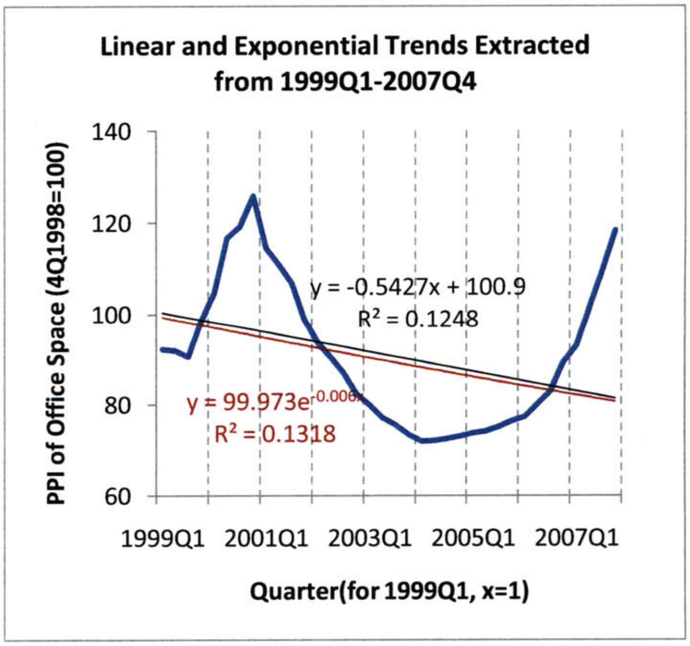

Linear and Exponential Trends Extracted from 1986Q1-2007Q4
PPI of Office Space (4Q1998=100)
200
160
120
80
40
0
1986Q1
1991Q1
1996Q1
2001Q1
2006Q1
Quarter (for 1986Q1, x=1)
y = 0.2968x + 82.109
R² = 0.0587
y = 73.81e^0.0045x
R² = 0.1152

(c)



Linear and Exponential Trends Extracted from 1993Q1-2007Q4
180
150
120
90
60
PPI of Office Space (4Q1998=100)
y = -0.9283x + 134.73
R² = 0.3108
y = 133.18e^-0.008x
R² = 0.3193
1993Q1
1996Q1
1999Q1
2002Q1
2005Q1
Quarter(for 1993Q1, x=1)

(d)



Linear and Exponential Trends Extracted from 1999Q1-2007Q4
140
120
100
80
60
PPI of Office Space (4Q1998=100)
y = -0.5427x + 100.9
R² = 0.1248
y = 99.973e^-0.006x
R² = 0.1318
1999Q1
2001Q1
2003Q1
2005Q1
2007Q1
Quarter(for 1999Q1, x=1)

(e)

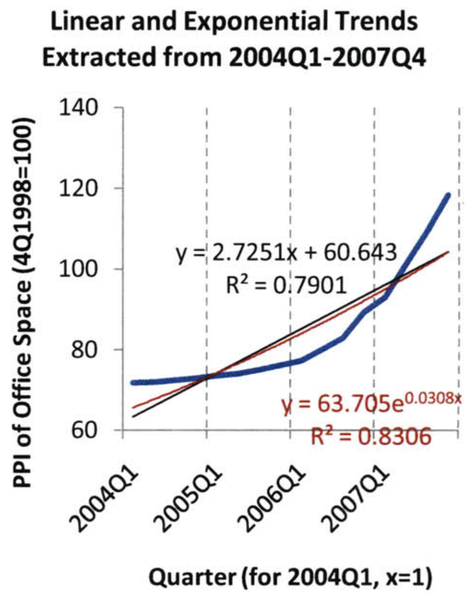


Figure 2.5: Trends and volatilities of Singapore office price index extracted from different periods excluding data in 2008 and 2009

Table 2.3: Comparison of Trends and Volatilities of Office Price Index Extracted from Data Series Including and Excluding Data in 2008 & 2009

Start of Data Series	Annual Growth Rate (%)		Standard Deviation (%)	
	Include 2008-2009	Exclude 2008-2009	Include 2008-2009	Exclude 2008-2009
1975Q1-	4.544	4.871	50.7	51.2
1986Q1-	1.719	1.820	32.4	33.5
1993Q1-	-2.332	-3.343	23.0	23.0
1999Q1-	-0.020	-2.360	18.2	15.8
2004Q1-	9.457	13.093	11.2	6.8

Through the real estate market of U.S. and Singapore, it is clear that the sensitivity of option value to these key inputs and the inability of getting reliable estimates of them is one of the reasons of the limited implementation of real options analysis in practice.

CHAPTER 3: OPTION-THINKING IN FLEXIBLITY DESIGN OF LONG-TERM INFRASTRUCTURE INVESTMENT

How can we best use option-thinking in flexibility design? This is the question this Chapter tries to answer, at least answer it from some perspectives.

Since uncertainty is the key driver of option value, the study of uncertainty itself should always be at the core of flexibility design. An in-depth study of (a) both the feature/nature of each uncertainty (b) and relationships among between different uncertainties, inside and outside of the project/investment is essential and extremely important to give rise of attractive real options. The former leads we identify the common problem for ROV showed in Chapter 2; and we discuss how to adjust both option-thinking and option valuation methodology to deal with the problem. The latter provides valuable information for flexibility design. The application of these concepts is shown though a true case – Dartmouth Hitchcock Medical Center.

Next this chapter covers possible directions of real options analysis in the future: migration of financial options application; Evolution inside real options itself, necessary support systems inside the organization. There are two important but neglected issues of ROA: On strategic level, real options analysis cannot be separated from the overall business strategies of the organization. On operational level, real options techniques cannot be treated as independent from other features of the organization (Gordon and Stark, 2000). Also, address the effect of competition on options value and the close tie between competitive strategy and option-thinking for infrastructure investment.

Finally, a framework of carrying out real options analysis in practice describes key steps of the implementation process.

3.1 An Essential Step of ROA: Sensitivity Analysis

Chapter 2 indentifies a common problem of real options valuation: the inability to get reliable estimates of key inputs describing the markets-based uncertainties. Since uncertainty is the value driver of options value, therefore the options value will be sensitive to the inputs which are used to describe the uncertain factors, such as trends and volatility of property price (see Figure 3.1), which also makes sensitivity analysis a required step.

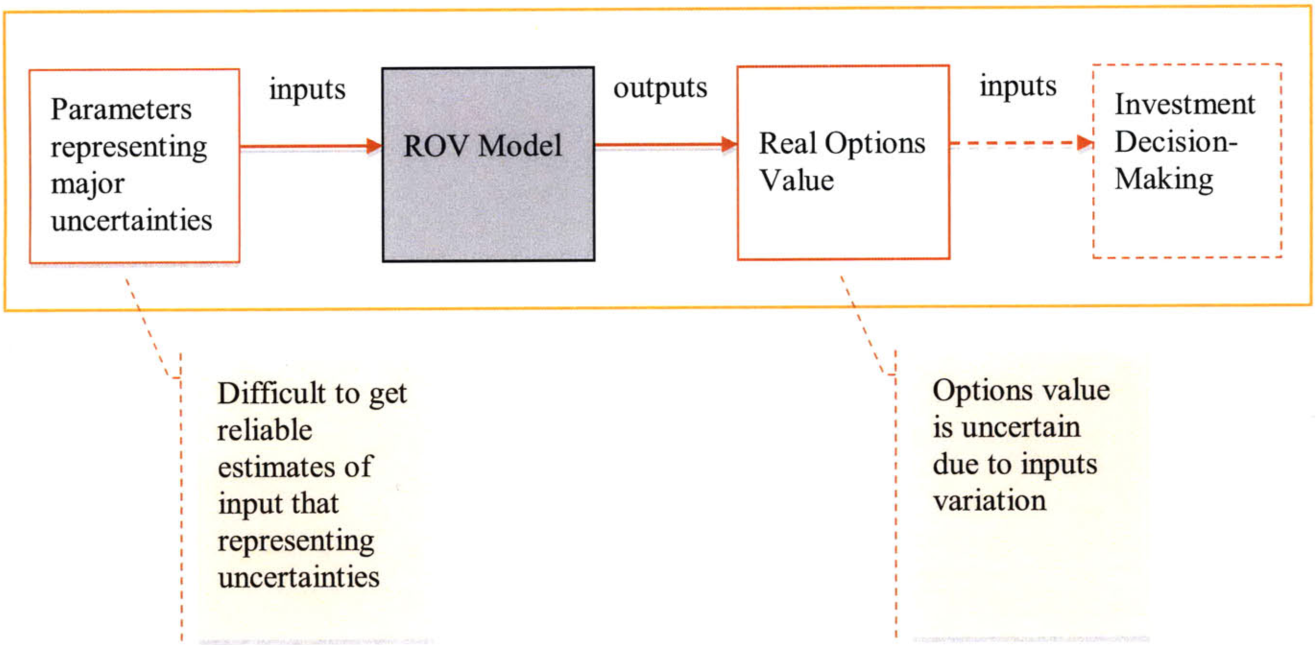


Figure 3.1: The origin of option value uncertainty

There are three levels of sensitivity analysis regarding ROV:

(1) The sensitivity of option value to different ROV model;

(2) For a given ROV model, the sensitivity of option value to key inputs (here trends and volatilities of market-based uncertainties) and the sensitivity of option value to decision rule;

(3) For a given ROV model and key inputs, the sensitivity of option value to correlations between different uncertainties.

In response to the identified barrier in Chapter 2, Chapter 3 focuses on the second level of sensitivity analysis. In reality, although we cannot identify the exact value of the inputs used to describe uncertainties, it is possible to get realistic estimates of the varying ranges of such inputs, based on expertise, experiences, historical data, etc. Actually, those different estimates of trends and volatilities of market-based uncertainties extracted from different data series can be used to construct the interval of each input. Also, managers/developers can leverage their expertise in their field at this point by influencing the choice of intervals of each input.

The sensitivity analysis provides us an interval of the expected options value (EOV), we term it "Expected Options Value Interval" (EOVI). Here is the process of executing the sensitivity analysis:

(1) The simplest situation is when only one input parameter is used to describe the major uncertainty and is difficult to identity the exact its value, we execute the typical sensitivity analysis and the get the EOVI.
(2) When there are two or more such inputs and they are uncorrelated, we estimate the range of each input and get all the possible combinations of them as inputs to calculate the EOVI.
(3) If these inputs are correlated (positively or negatively), we need to estimate the correlation parameters among them first before calculating the EOVI.

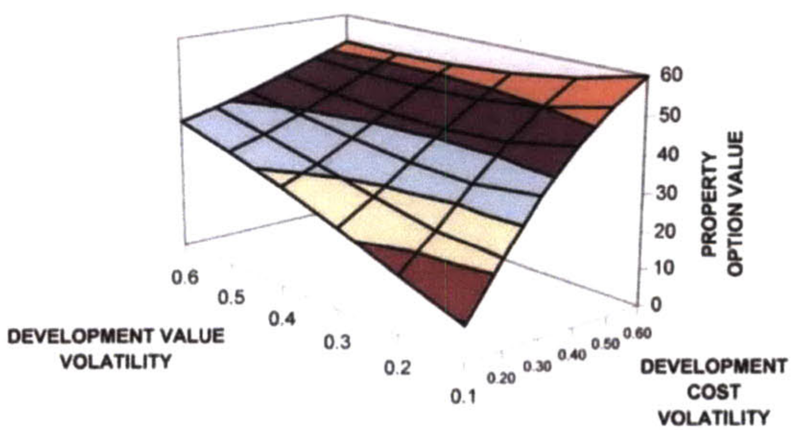


Figure 3.2: An Example of Sensitivity Analysis of Real Options Value

The sensitivity analysis provides us with an interval of the options value instead of a specific point value, which is different from the financial options. Whereas financial options are well-defined traded contracts, real options are priori undefined, complex, and interdependent. For financial options, the owner requires a specific price to trade it on the financial market. But for real options, the option owner usually uses it as an input for strategic decision-making; we can therefore compare the option value interval with the critical value that will reverse the decision-making. In this sense, sometimes an interval is good enough for real options analysis.

3.2 Facing Uncertainties: Change the Perception of Uncertainty from Risk-focused to Opportunity-focused through Option-thinking

Facing uncertainty, Drucker (2004) pointed out "If general perception changes from seeing the glass as 'half full' to seeing it as 'half empty,' there are major innovative opportunities." Traditionally, people perceive uncertainty as origins of risk. Real options analysis, to the contrary, views uncertainty as the key driver of options value. They have different, even opposite perception of uncertainty: the former is risk-focused while the latter is opportunity-focused.

The difference in perception of uncertainty provokes different strategies to deal with uncertainty accordingly. de Neufville (2003) analyzed the essential differences of setting strategies in system design under traditional perspective of uncertainty and option-thinking perspective.

> "To think in terms of options alters the way one deals with uncertainty. Conventionally, good design minimizes risk. It focuses on increasing reliability and making the best decisions in risky situations. In short, it is reactive to risk. The framework of options thinking, however, recognizes that uncertainty adds value to options. In this context, uncertainty is a driver of value and can be viewed as a positive element. Correspondingly, systems design from this perspective is proactive towards risk. It seeks out opportunities to add value and commits to ongoing processes of information gathering to ensure that options can be exploited at the correct time." (de Neufville, 2003)

In light of this comparison, we iterate real options analysis is not "risk-focused" but "opportunity-focused" in dealing with objective uncertainties. However, a common but widespread misunderstanding of real options analysis is that "it encourages risk-taking." As Chapter 1 indicates, the survey conducted by Block (2007) identified this as one of the top four reasons why managers refused to use real options analysis in practice. Therefore, special attention and efforts are desirable to communicate the right concept of option-thinking between academia and practitioners.

3.3 Dealing with Uncertainties: Flexibility Design based on Uncertainties Interaction

Since uncertainty is the driver of the option value, the study of uncertainty itself should always be at the core of flexibility design. An in-depth study of

- The feature/nature of each uncertainty
- And relationships among different uncertainties, inside and outside of the project/investment

is essential and extremely important to give rise to attractive real options. The nature of certainty itself leads us identify the common problem for ROV model; here, we show that studying the relationships/correlations between uncertainties can cast light on designing real options for the project.

Previous Study of Uncertainties

As mentioned earlier, the nature of uncertainties should be at the core of real options analysis. However, it seems there is limited research on it. Available study about uncertainty is about its categories: endogenous and exogenous uncertainty (Braeutigam et al, 2003). By dividing uncertainties in different sectors, such as intangible, financial, product, market, regional, we can choose certain options from defer, abandon, expand, contract, and switch (Figure 3.3).

Source: Own illustration *Similar: Benaroch 2002*

Figure 3.3: Option-Uncertainty Matrix (Braeutigam et al, 2003)

3.3.1 Negatively/Non- Correlated Uncertainties: Reactive Flexibility

Let us begin with a simple example to show the rationale. A retail store selling umbrellas faces the high uncertainty of the weather: when it is rainy, sales are high; when it is sunny, sales are low. The retailer can consider the option of selling sunglasses. When it is rainy, the umbrella sale is high; when it is sunny, the sunglasses sale is high. Success comes from (a) opportunity-focused perception of uncertainty of weather (b) and designing an option based on the negative correlation between the sales of umbrella and of sunglasses.

This is similar to the "Portfolio Theory" of investment. There are two kinds of risks: diversifiable risk (non-systematic risk) and non-diversifiable risk (systematic risk). A portfolio is simply a collection of assets. And the portfolio return is defined as the weighted average of the individual asset returns. Modern portfolio theory (MPT) tries to maximize return and minimize risk by carefully choosing different assets. MPT is a mathematical formulation of the concept of diversification in investing, with the aim of selecting a collection of investment assets that has collectively lower risk than individual asset. This is possible in theory because different types of assets can change value in opposite ways. For example, when the price of one stock falls, the prices of some other stocks can increase, and vice versa. A collection of both types of assets can therefore have lower overall risk than either individually.

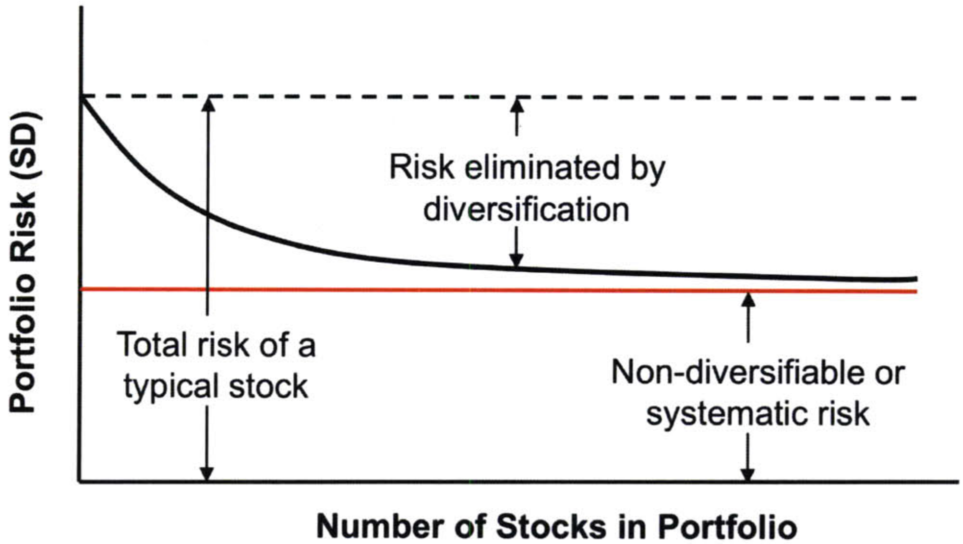


Figure 3.4: Impact of diversification on portfolio risk (Verdelhan, 2010)

For the project under consideration, if we can identify uncertainties that are negatively correlated to some extent, then we can design real options based on this correlation from portfolio management perspective. Here are two typical examples of using diversification to create flexibility in infrastructure investment:

- "Building a production system that can change easily from one input to another or from one product to another" is equivalent to creating a switch option. "Thus dual-fuel burners that can use either oil or gas give the operators of power plants the right to switch between fuels whenever it is economical to do so. Likewise, production lines designed to switch equipment so that they can produce different products give managers the right to do so when they wish (de Neufville, 2003)." This kind of switch option is based on the fact that the market price of oil and gas, or the prices of different products, may be negatively correlated to certain extent. By bundling the options together as a "portfolio", it is possible to manage the infrastructure more economically efficient.

- By carefully selecting the "portfolio" of different tenants in a property, the property owner can effectively hedge the risk of market demands for different kinds of renting space. The historical space demands of different types of tenants will give the owner clues for constructing the "tangent portfolio" [1] of tenants.

This kind of flexibility is "reactive flexibility" – the option holder responds to environmental conditions to maximize the payoff (Leslie and Michaels, 1997). Reactive flexibility is what management always intuitively applies in decision-making, even before real options analysis coming into main stream.

The rationale of portfolio theory is: diversification reduces risk. Mapping it to real options design, the lesson we learn is that we can increase the return of infrastructure investment by incorporating bundle-type real options give some of the uncertainties are negatively correlated. And such uncertainties are the "diversifiable uncertainties" (or "non-systematic uncertainties") of the infrastructure investment. If the premise that some uncertainties influencing option value are negatively correlated or non-correlated is not satisfied, we needs to consider different strategies as discussed in the next section.

However, it is not true that the more diversification is always the better. There are limitations because the potential diversification approach needs to fit the overall company-level sustainable strategy. As Porter (1998) indicates, strategy is creating fit among a company's activities and the success of a strategy depends on doing many things well and integrating among them. Moreover, there is no distinctive strategy and little sustainability if there is no fit among activities. An example for this was Neutrogena soap, which is the Neutrogena Corporation's "kind to skin," residue-free soap formulated for pH balance. The company positioned it as a drug-like soap compared to common softening soaps, and uses a slow, more expensive manufacturing process to mold this fragile soap. It is hard for, Ivory soap, with its position as a basic, inexpensive

[1] Tangent Portfolio is the one that has the highest possible Sharp Ratio of all possible portfolios; Sharp Ratio is a measure of a portfolio's risk-return trade-off, equal to the portfolio's risk premium divided by its volatility.

everyday soap, to straddle Neutrogena and diversify its product line to include similar drug-like soap. Because there is trade-off for this diversification: the inconsistencies in image or reputation: A company known for delivering one kind of value may lack credibility and confuse customers – or even undermine its reputation – if it delivers another kind of value or attempts to deliver two inconsistent things at the same time. There may be trade-offs of diversification since a sustainable strategy requires fit among different activities, which can limit the application of diversification in some situations. Porter (1998) showed three kinds of trade-offs for a sustainable strategy: (1) the first trade-off is inconsistencies in image or reputation as showed in the example above; (2) trade-offs arise from activities themselves and reflect inflexibilities in machinery, people, system and so on; (3) finally, trade-offs can arise from limits on internal coordination and control; for example, companies that try to be all things to all customers risk confusion in the trenches as employees attempt to make day-to-day operating decisions without a clear framework. In a nutshell, inactive flexibility's power as well as its application is limited to deal with various uncertainties we may face.

3.3.2 Positively Correlated Uncertainties: Proactive Flexibility – the True Beauty of Option-thinking is to Expand Your Vision

What if ONLY positively correlated uncertainties[2] or JUST ONE major uncertainty are involved in the infrastructure? In such situation, diversification does not work since we do no have other resources of uncertainties which are behaving in the different/opposite direction.

But the real power of real options is more obvious when dealing with such situation involving only positively correlated uncertainties since this is where proactive flexibility comes in its way. Compared to reactive flexibility in the Section 3.3.1 which aims to mitigate uncertainty and respond to external conditions at decision-making time, proactive flexibility is designed to seek gains from uncertainty and maximize learning by keeping options open and expanding the decision-maker's vision on strategic level. We analyze why proactive flexibility can do so from

[2] Here we consider the dominating uncertainties and ignore insignificant uncertainties although they may be uncorrelated or negatively correlated.

different perspectives. The case of Dartmouth Hitchcock Medical Center shows how proactive flexibility is applied in long-term infrastructure investment.

Use Proactive Flexibility to Seek Gains from Uncertainty and Maximize Learning

First, the value of keeping one's option/position open is clearest in investment-intensive industries, such as real estate, hospital, oil extraction and so on, each pursued or abandoned according to the results of the previous stages. Excellent performers instinctively or intuitively view their investment opportunities as real options, positioning themselves to tap possible future cash flows without making a final decision to invest until the potential is confirmed. Making one-time decisions on the basis of static investment plans tends to narrow the vision, making it difficult to change course in the future. The option valuation recognizes the value of learning. This is important because strategic decisions are rarely one-time events, particularly in long-term infrastructure investment typically involving several stages as well as lots of uncertainties (both technical and political).

Second, although it is hard or even impossible to have an infrastructure designed "perfectly" today still be "perfect" or up-to-date 20 or more years later, proactive flexibility enables the infrastructure to keep "updating" frequently. The initial design works as an open platform, on which later stages can be built on using state-of-art technologies. The key here is what you build today should not limit what you want to update tomorrow, but be a supportive platform to appreciate future stages.

Third, option-thinking, especially proactive flexibility, is distinguished from their traditional counterparts above all by their response to uncertainty. The shift in outlook from "fear of uncertainty and minimize investment" to "seek gains from uncertainty and maximize learning" opens up a wider range of possible actions and is crucial to the usefulness of real options analysis as a strategic tool rather than a valuation model.

Forth, the discipline of incorporating proactive flexibility to every investment possibility will improve a company's strategies in four ways (Leslie and Michaels, 1997):

(1) Emphasizing opportunities

(2) Enhancing leverage: real-options strategies promote strategic leverage, encouraging managers to exploit situations in which incremental investment can keep their companies in the game. This is different from simultaneous investment in multiple opportunities, which reduces the upside as well as the downside. Thus, leverage distinguishes real-option strategies from traditional diversification strategies that reduce risk.

(3) Maximizing rights

(4) Minimizing obligations

The application of real options steers management toward maximizing opportunity while minimizing obligation, encouraging companies to think of every situation as an initial investment against future possibility. As a result, management's field of vision is extended beyond long-term plans too rarely reexamined in order to encompass the full range of changing opportunities. Option thinking achieves this through its most basic contribution and most striking departure from the dictum of NPV: the attitude it fosters to uncertainty.

Last but not least, the proactive flexibility approach tends to increase the value of an option once acquired. As Leslie and Michaels (1997) indicate, this opportunity arises from one of the key differences between real option and financial option. While a financial option is acquired and exercised in a deep and transparent market, real business situations usually feature a limited number of players – each able to influence a few specific levers that control the value of real options – interacting with one another. Thus, managers can use their skills to improve an option's value before they actually exercise the option.

Among the six levers[3] that drive option value, which you choose to pull depends on the internal and external constraints on the operations of the company. These constraints might be technical, or they might have to do with marketing, negotiating, or contractor management issues. They would also consider investment factors such as the delay between investment and payoff, as well as constraints on incremental investment.

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[3] The six levers are present value of expected cash flows from investment, present value of required investment costs in real assets, volatility of underlying cash flows, period for which investment opportunity is available, cash flows lost to competitors, and risk-free interest rate.

Proactive Flexibility in the Case of Dartmouth Hitchcock Medical Center Evolution

Making long-term infrastructure investment decisions in an uncertain market is like swimming in uncharted water. Option-thinking opens your vision on a strategic level and changes the way management thinks by adopting proactive flexibility when making irreversible investment decisions. The Dartmouth Hitchcock Medical Center (DHMC) is a perfect case to show the true beauty of proactive flexibility. It is located near London, New Hampshire, and was built during 1988-1991 when the old site run out of space. The building is occupied by three groups of stakeholders: the Dartmouth Medical School, Mary Hitchcock Memorial Hospital (MHMH), and Dartmouth-Hitchcock Medical Clinic.

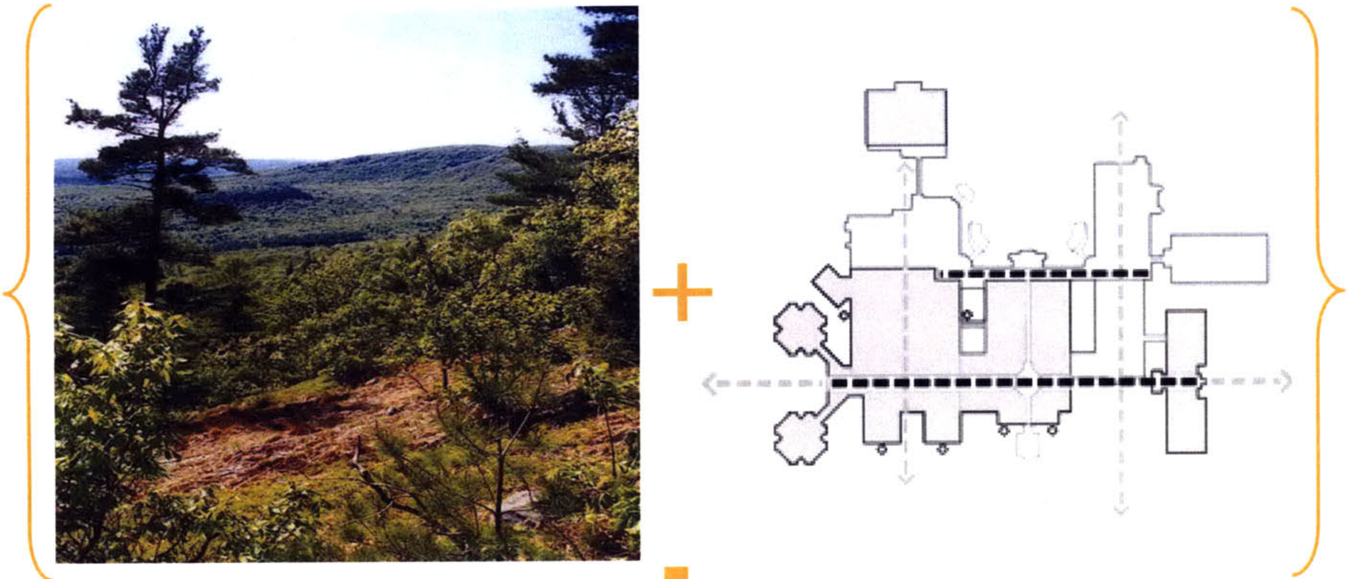
Table 3.1: Timeline of Dartmouth Hitchcock Medical Center (Source: Watson, 2010)

Time	*Key Actions*
1797	Dartmouth Medical School (DMS) was founded by Dr. Nathan Smith. DMS is the fourth-oldest medical school in the country.
1893	Mary Hitchcock Memorial Hospital (MHMH) was built by Hiram Hitchcock in memory of his wife, Mary Maynard Hitchcock.
1927	Dartmouth-Hitchcock Clinic (DHC) was established by a group of five physicians
1980s	Dartmouth-Hitchcock Medical Center began planning for a new facility. Construction of the $228 million project began in 1988 on a 225-acre wooded site in London, New Hampshire.
1991	On October 5, 1991, the new Dartmouth-Hitchcock Medical Center facility opened for business. One of the few completely new medical centers in the country, the complex is designed for patient convenience and comfort with an ambiance of warmth and openness.
2004	In August 2004, the New Doctors Office Building opened, increasing the campus by 40%.

During the planning stage of DHMC in 1980s, the boards invloved were really thinking about to build an infrastructure that makes sense not only at the that time but also for the future. Because they don't want to move in probably another 100 years since it costs a lot to move again. For long-term infastructur design like DHMC, the design team realized it was dangerous to use the user meeting as the primary driver for the hospital's design as a whole, because, more often than not, people involved in the user meeting were not going to occupy the building in the long-term. Realizing this fact, the design team applied three critical principles to ensure DHMC adaptability to identified key uncertainties:

- First, make uncertainty as one of the primary drivers of the long-term hospital design.
- Second, allowance to expand is always of part of the thinking for both the overall design and the design for a particular unit (various proactive flexibilities design incorporated).
- Third, phase the development appropriately; particularly, later phases will not be built until demand/requirement is confirmed.

These three principles guided the proactive flexibilities built in the infrastructure, which contributes greatly to keep DHMC up of date in the long term through handling evolution of uncertainty factors effectively. The following shows the actual process of DHMC through three parts: identify key uncertainties of hospital design, the critical proactive flexibilities in the design and the lessons from one completely inflexible component of DHMC.



a) Landparcle before construction

b) Design of DHMC

c) Construction completed in 1991

Figure 3.5: Dartmouth Hitchcock Medical Center from 1988-1991 (Source: Watson, 2010)

Identify Key Uncertainties in Hospital Infrastructure Design

A most significant uncertainty is fast development speed of healthcare technology. The infrastructure should be adaptable in order to locate new and advanced equipment in the hospital. Size of room, floor height, the infrastructure strength (some equipments can be really heavy) are the parts of perspectives the design team needs to consider. For example, imaging technology and surgeon technology require very complex rooms. The Figure below shows how fast the GAMA technology has evolved in only about two decades; and nobody really knows what is going to happen in the next step.

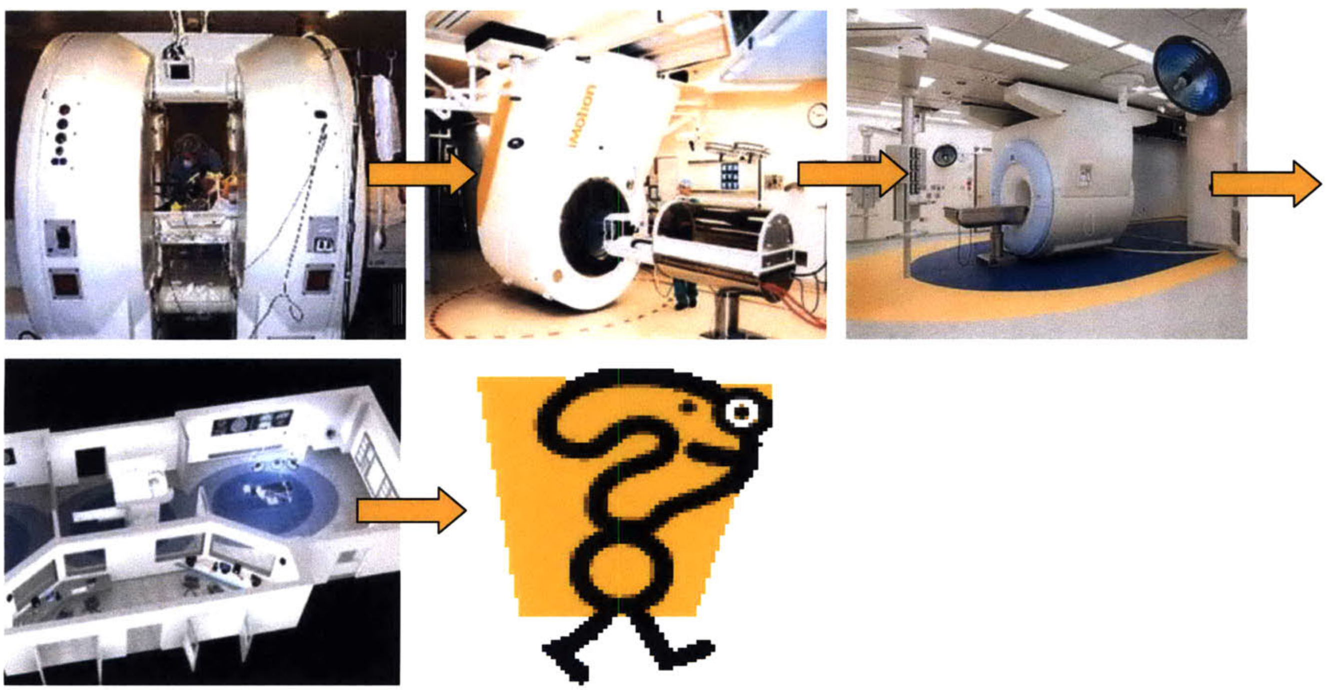


Figure 3.6: Evolution of Imaging Equipment for Healthcare in Two Decades (Source: Watson, 2010)

The second source of uncertainty is the demand for health care service, such as the demands for inpatient rooms, clinical space, parking space, etc, which is closely related to local demography.

Finally, the health care policies also bring significant uncertainty to requirement of the infrastructure.

Proactive Flexibilities Built in the Infrastructure

Using identified key uncertainties as one of the primary drivers of the design, different proactive flexibilities were incorporated into the infrastructure. For example, how to implement capacity to add more elevators and stairs if the size of the building doubles; how the access the buildings from many entrances; how to locate the common elements and utility systems to ensure their capacity can grow with demand and in the meantime different elements are all able to access them. As for more detailed designs, an example is the floor height. It was the same all through the building, and was designed higher than the typical height at that time, which services them very well to date. This section focuses on three most critical proactive flexibilities: outside utility plant, horizontal phasing, and vertical phasing.

Proactive flexibility I: Outside utility plant (Heating, Cooling, Emergency, Deliveries)

A really important decision was the location of the utility plant, which the heating, cooling, emergency and deliveries. Instead of locating inside the infrastructure just like the typical approach, they decided to put the utility plant outside of the building. In other words, not bear it in the building but put it at some place that is serviceable and out of the way (Figure 3.7). This costs an extra million of dollars at that time, which they could used to build more units. This anti-intuitive decision, however, was a key proactive flexibility actually. By putting it outside of the infrastructure, it is easy to add extra capacity of heating, cooling, emergency, and deliveries without worrying about running out of space. Moreover, it is also comparably easier to update these systems as technologies developed.

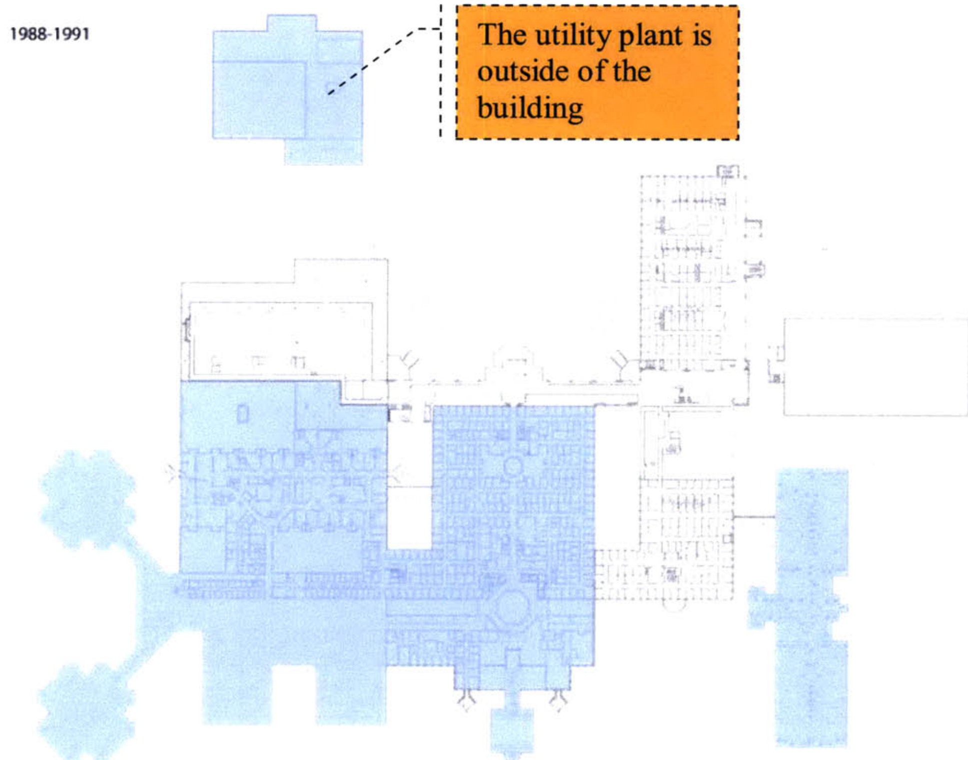


Figure 3.7: Outside Utility Plant of DHMC (Adopted from Watson, 2010)

Proactive flexibility II: horizontal phasing appropriately

Having various flexibilities enables the building to grow in the future in place, then the next thing is the timing of each growth step. The organization of different apartments and different relationships among them around the major infrastructure was well designed to support its growth. Horizontal phasing is the most obvious flexibility in the whole development process, as shown in Figure 3.8. This reflected the second principle listed the in the beginning of the DHMC case that "do not build until demand/requirement is confirmed."

There are at least two kinds of benefits by phasing the development appropriately:

- Financial benefits from delaying cash outflows of later phases including costs of construction, operation, maintenance, and so on.
- Take advantage of advanced or new technologies by building later instead building all at once.

- As time passes by, not only technology changes, also people's taste of what a hospital should be. As for hospital design, it is really not only about flexibilities, also the way to delivery healthcare service to people, which is evolving all the time. Phasing the development process gives DHMC the time and opportunity to learn and keep its position open to benefit from the learning.

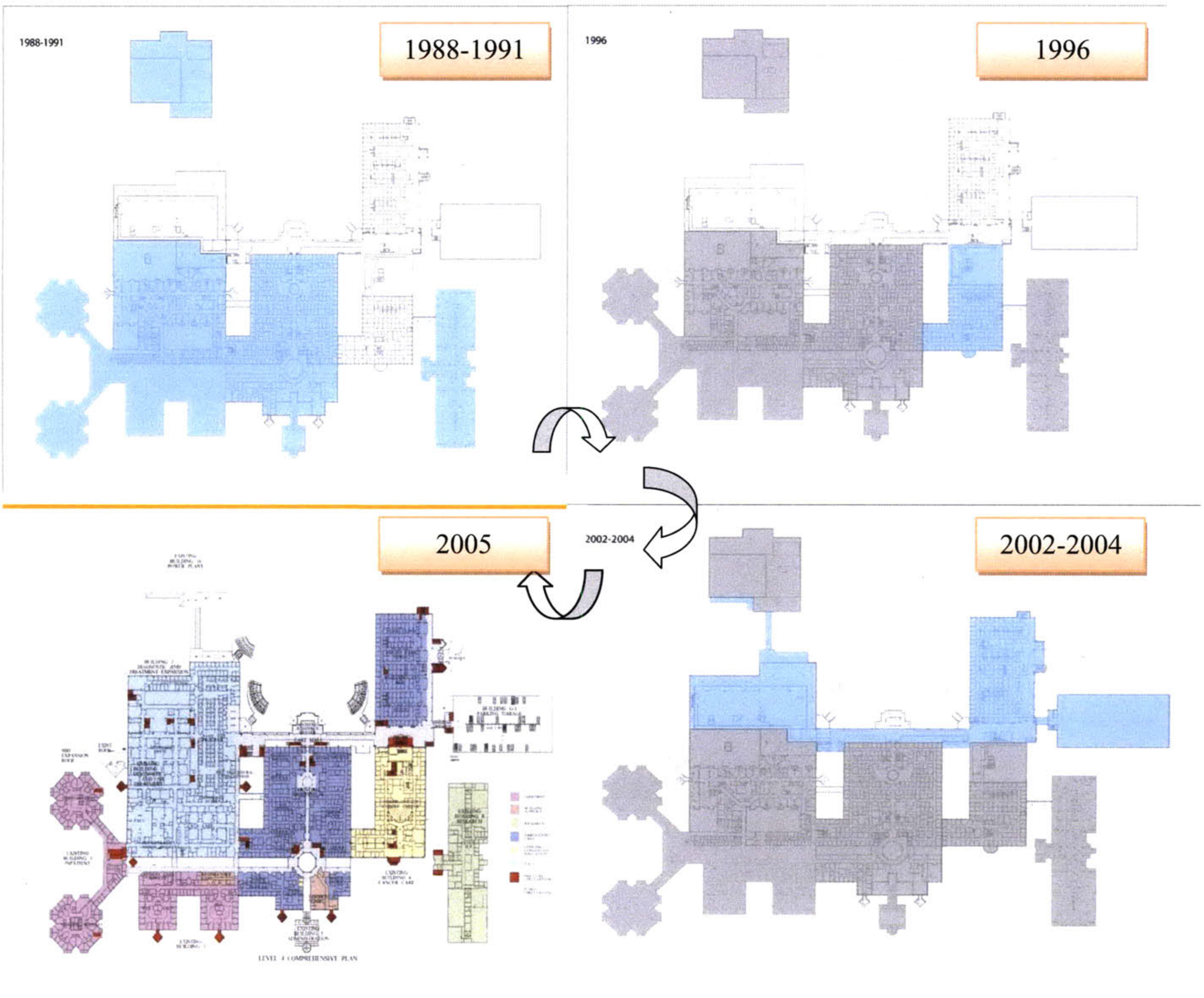


Figure 3.8: Proactive Flexibility II – Horizontal Phasing of DHMC from 1988 to 2005 (Adopted from Watson, 2010)

Proactive flexibility III: vertical phasing of Cancer Research Building

The building filled with yellow is the Cancer Research Building. It had been vertically expanded during the development process.

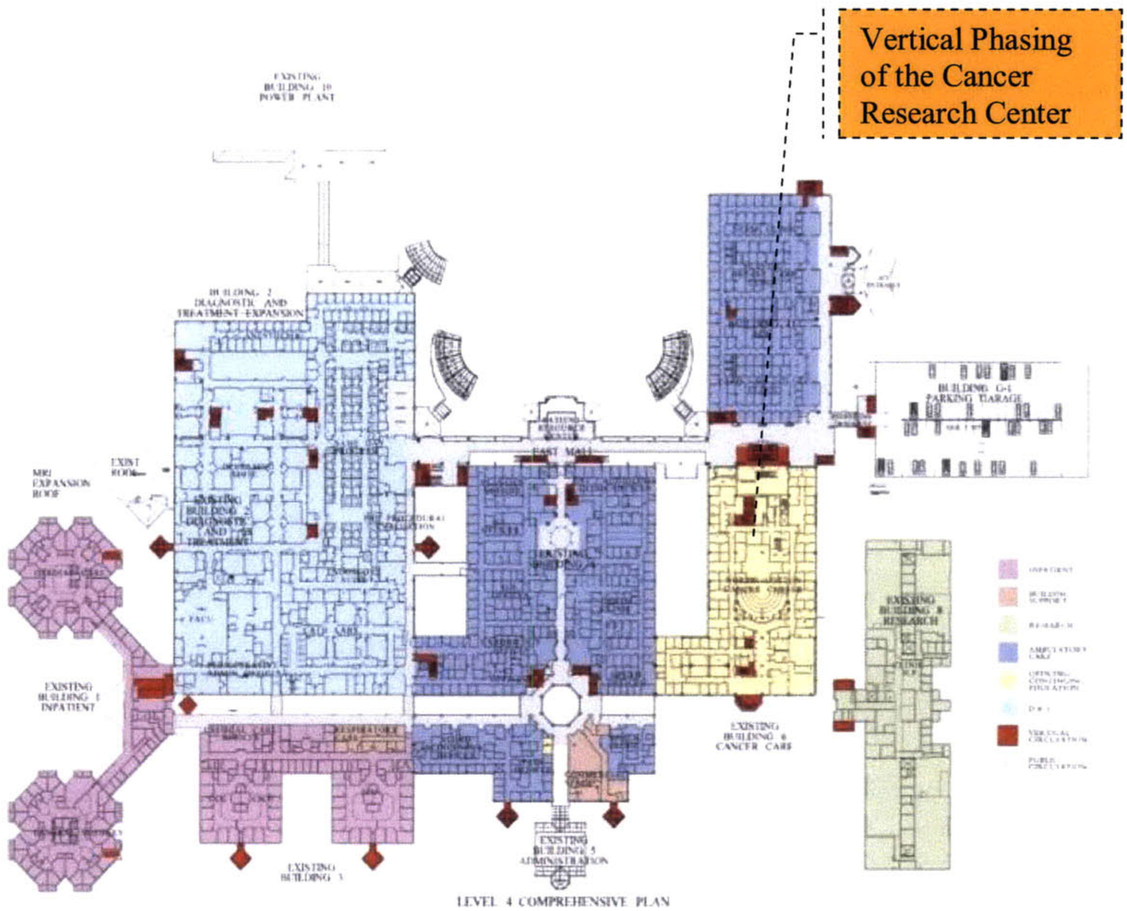


Figure 3.9: Proactive Flexibility III – Vertical Expansion (Adopted from Watson, 2010)

<u>Lessons from an Inflexible Component of DHMC</u>

The design of the inpatient rooms were the completely inflexible components of DHMC, which gives rise to several problems they are suffering right now. This inpatient area was designed as two "rings": the function area[4] (treatment, equipment, support, etc) is at the center of the "ring",

[4] The function area is filled in yellow in Figure3.10.

while inpatient rooms[5] are around. There critical problems[6] of this inflexible component are: (1) there no space to expand the function area due the limitation of the size of the closed "rings"; in other words, you simply build two circles for yourself and you can grow nowhere; (2) run out of impatient rooms due to the same reason. However, it is just impossible for them to tear this part down and rebuild, because if so where should they locate all the patients during the construction period. There is just no time that a hospital does not have any inpatient.

The possible future regulation of healthcare may make the situation worse by requiring more space. Certain policies are proposed to have only single inpatient rooms. However, there are only two people rooms and three people rooms at this moment. In the future, it is more possible than not that you will suffer from many respective for a completely inflexible design.

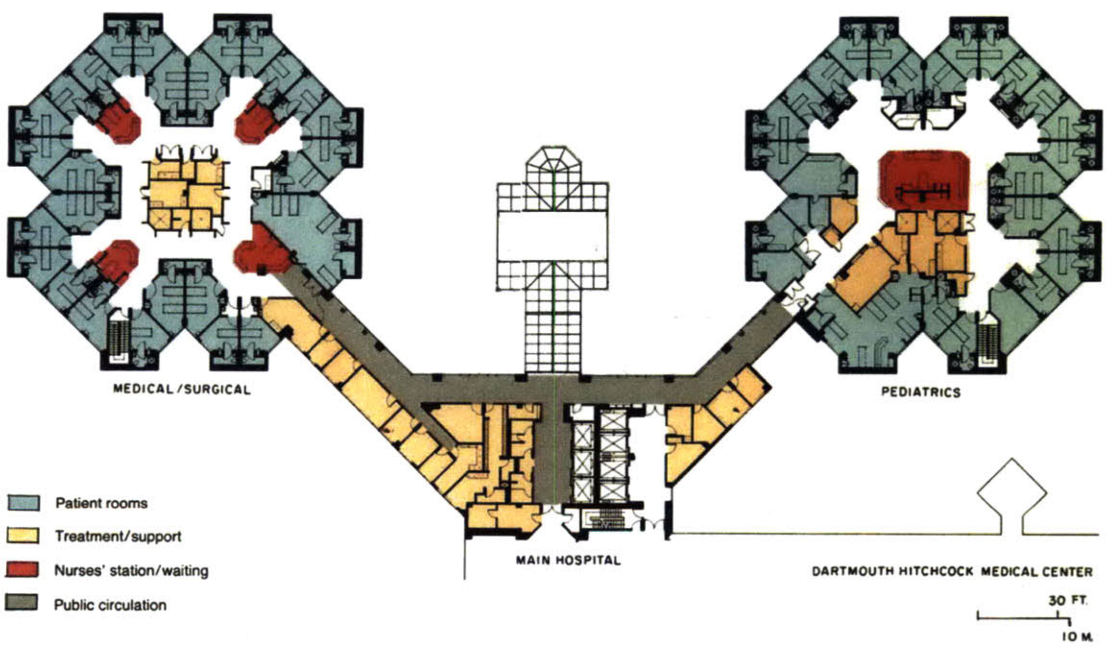


Figure 3.10: Inflexible Design of the Inpatient Rooms (Watson, 2010)

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[5] Inpatient rooms are filled in green in Figure 3.10.

[6] Another critical problem is the although the design of this component enables the nurses to monitor the several inpatient rooms efficiently at the same time, it is very confusing for the patients and their family when walking around since it is very hard to recognize direction in a ring like building.

Case Summary

Proactive flexibility gives rise to an infrastructure design that makes sense for both now and the future. This happens when the design use uncertainties, not the requirements from the user meeting, as one of the primary drivers of the design. Although, certain designs of details in the DHMC case are directly related to hospital design, most principles on general design apply to other long-term infrastructure proactive flexibility design. Also, a lot of problems will probably arise from a design with no allowance of growth in the future.

Another real interesting thing about the project is that a very consistent group of people are involved in the whole process. This is extremely important for a long-term infrastructure design contains several phases. Because it ensures that members in the design team understand the concept behind the whole infrastructure and be on the same page.

3.4 Commercial Real Estate: How Competition Shapes Real Options Analysis

Real options analysis for commercial real estate cannot avoid the topic of competition. Competition not only influences the optimal exercising time of real options, it also affects the specific design/choice of real options in the planning stage.

From real options to competitive strategy

Strategy can be viewed as a chain of real options interacts with one another. Since much of the value of the real options approach comes from strategy, it is essential to properly frame the investment strategy (Copeland and Howe, 2002). The relationship between real options and strategic decision making is bi-directional (Myers, 1984): strategy influences real options, while the valuation process influences strategy. Discovering the potential of strategy is not the only benefit of the real option framework. The process of real option valuation also allows for optimizing the strategy with regard to strategy execution (Micalizzi and Trigeogis, 1999). Also, the value of many decision rules lies more in the requirement for consistency than in optimality (Bowman, 1963). The same is true for real options.

From Interaction of Uncertainties to Interaction of Real Options

We can design real options by considering the nature of interaction between uncertainties. At the same time, we form real options exercising strategy by revealing the interaction between real options. There is a link between these two kinds of interactions regarding that several options may be control the same uncertainty and several uncertainties are involved in one specific option.

Investigate the Role of Competition of Real Options Valuation

Some researchers argue that real options models have limited power to predict investment in competitive markets (Bulan et al, 2009) by showing competition may significantly reduces the sensitivity of option exercise to volatility/uncertainty.

Schwartz and Torous (2003) find that the competitive nature of local commercial real estate market has a significant effect on building starts: less competition is associated with fewer building starts. Bulan et al, (2009) find increases in both idiosyncratic and systematic risk lead developers to delay new real estate developments by examining the condominium developments in Vancouver and Canada between 1979 and 1998; Increases in the number of potential competitors located near a project negate the negative relationship between idiosyncratic risk and development. Their results support models in which competition erodes option values to delay irreversible investment and provide clear evidence for the real options framework over alternatives such as simple risk aversion. Their results are consistent with Caballero (1991), Trigeorgis (1996) and Grenadier (2002), who argue that competition diminishes the value of defer option (waiting to invest). And they also conclude that competition only impacts investment indirectly through its correlation with uncertainty.

Competition may limit available real options. While financial options are exclusive, real options may be shared. While competitive interactions may be modeled by combing real options and game theory, the approach is quite complicated for a practitioner (Dixit and Pindycky, 1994). Then, the question is how to incorporate the concepts of game theory into real options model so that the analysis can better explain real world investment decisions.

It is worthwhile to note that previous research only focuses on the relationship between competition and real option exercise since the real options approach is only valuable when options are *exercised* effectively. But it is equally important, if not more, to address the relationship between competition and real options *design.*

In the future, not only competition will shape real options analysis, option-thinking will also be widely applied on strategic level and thus shape future competitive strategies.

3.5 Two Issues with ROA: Align with Management Strategy and Build Organization Support

Align "Managing for the future" (Drucker) and "Designing for the Dynamic"(de Neufville)

We will see increasing links between real option thinking and the broader aspects of business strategy and marketing. Firms will set strategies that optimally create chains of options, and they will offer products and services, which make optimal returns from the real option values that offer to the customers. Finally, the loop of activity will close back to the financial markets – firms that find they have unacceptable exposures in the real assets arena might seek suitable hedges in the financial market.

Organizational Support

Real options techniques cannot be treated as independent from other features of the organization/company (Gordon and Stark, 2000). Two systems are necessary to assure the application of real options analysis in an organization's decision-making

- The availability of ***Information systems*** capable of providing the necessary data for the appropriate exercise of flexibility.
- The availability of ***Incentive systems*** capable of motivating managers to exercise flexibility in the interests of shareholders.

3.6 Framework of Applying ROA

Braeutigam et al, (2003) proposed a framework for the application of real options valuation that can be processed sequentially. This framework is organized across four layers involved in the whole process: organizational-, strategic-, valuation-, and controlling aspects of real options (Figure 3.5).

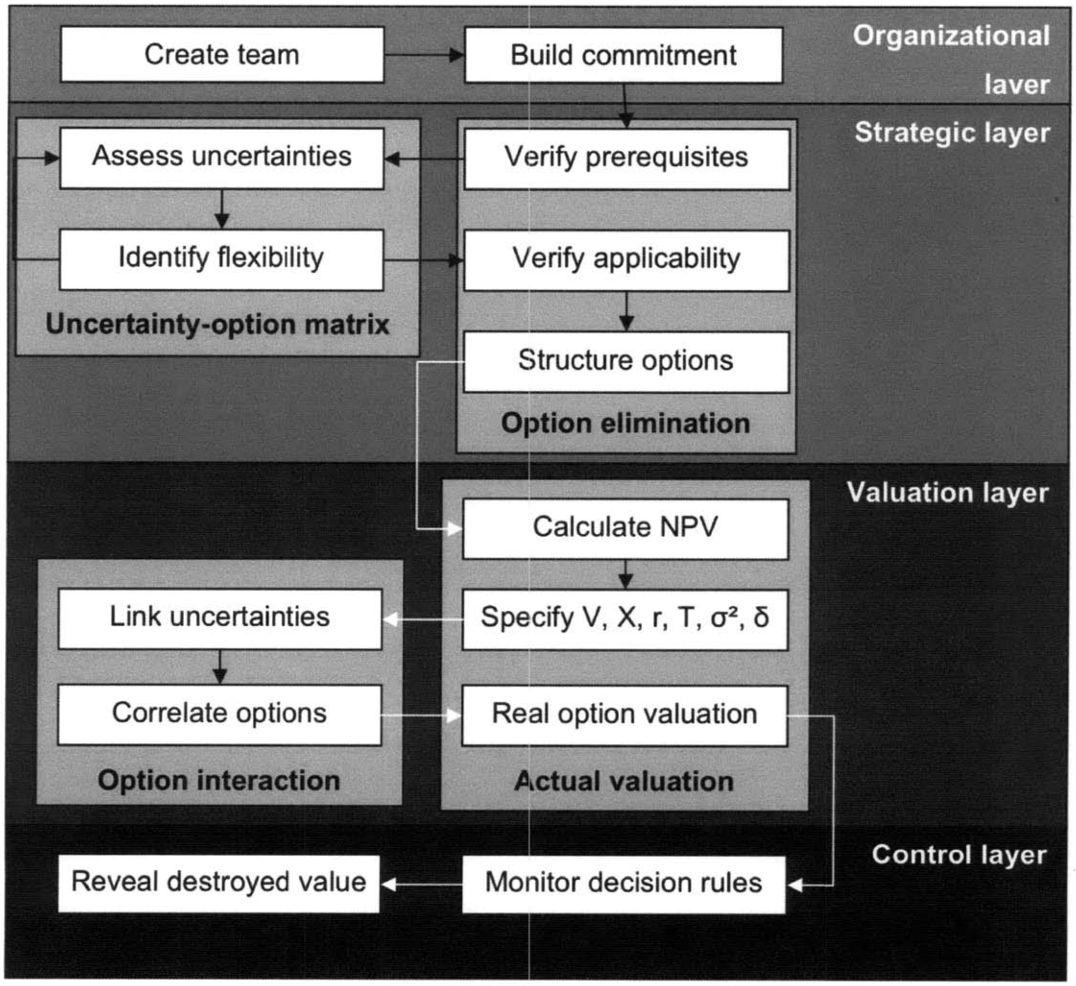


Figure 3.11: Framework of Applying ROA (Braeutigam et al, 2003)

This is a very general framework described the key steps to apply ROA. Two more detailed levels of framework should be developed:

- Industry-level framework: combine this general be combined with specific industry characteristics to develop an industry specified second level framework. On this level, factors that can reflect the features of a particular industry need to be taken into account, including, but are not limited to, the cycles of the industry, development speed, market segmentation, etc.

- Company/Organization-level framework: combine the industry-level framework with the specific situations of the company/organization to craft a framework that is able to be adopted by the company/organization. On this level, factors need to consider including, but not limited to, the management structure, the resources, the culture/style, overall strategy, competitive advantages.

While the industry-level frameworks can be developed by the academia to ease the application of ROA in that industry as a whole, the company/organization level frameworks is really a burden of senior management of the company/organization themselves since they are the people who really know about their company/organization. Actually, the latter can also be done by hiring a management consulting company to assist this process.

CHAPTER 4: CASE STUDY - A MIX USE COMMERCIAL REAL ESTATE DEVELOPMENT

This chapter applies the option thinking and engineering-based real options valuation approach to a real world commercial real estate development based in Singapore – Central.

4.1 Background of Central

Central is a typical mix-use commercial real estate property developed by Far East Organization (FEO), which is the largest private real estate company in Singapore with total asset value over $40 billion. FEO's operations span Residential, Hospitality, Commercial, Retail and Industrial sectors. FEO comprises privately-held development and investment companies, and two public-listed companies, Orchard Parade Holdings Limited and Yeo Hiap Seng Limited.

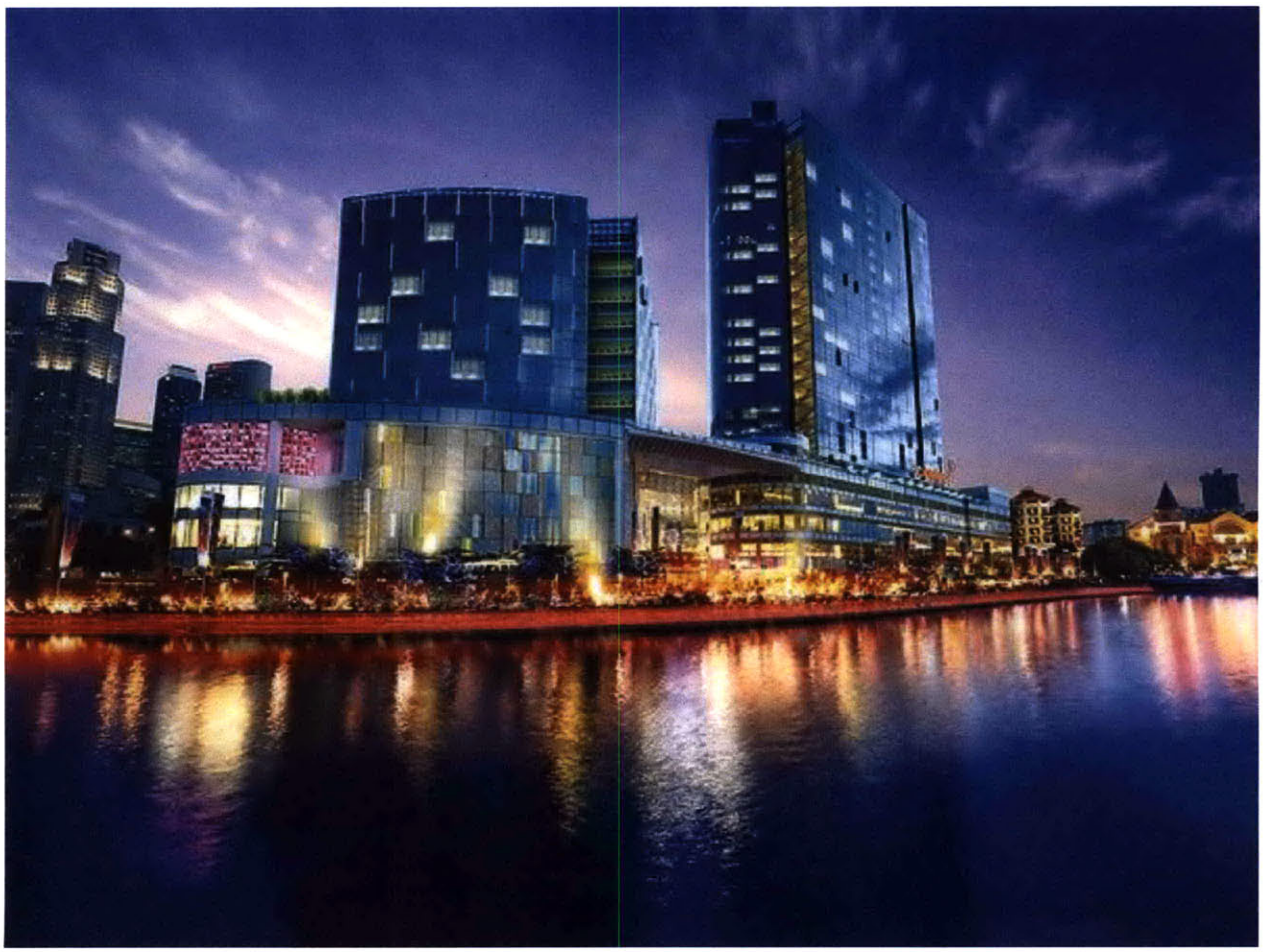


Figure 4.1: Central (Source: Far East Organization, 2010)

Central is above the Clark Quay train station. In Singapore, the train system, as the primary public transportation choice, is every efficient. Therefore, setting above a train station is always a huge advantage. The podium is a shopping mall; above it sits four towers. Two towers were designed as Small Office Home Offices (SOHOs), one tower is a New Age Office (like SOHOs) and the forth is a regular office building. The shopping mall was Phase 1 and there are several phases for the rest of the development. This is a typical "staged development" in Singapore. For staged development, the government gives the developer a deadline (called "completion period") by which the whole development must be completed. But the developers are given the flexibility to choose the deadline for each phase as long as it is within the completion period required by the government. So, FEO can determine the timeline of the four towers within the completion period. This Podium-Tower structure is widely applied to mix-use commercial development in Singapore.

Location, Location, and Location

There are mainly two zoning areas in Singapore according the Urban Redevelopment Authority (URA):

- Central Area (Downtown Core Planning Area and Orchard Planning Area)
- Fringe Area

"Central" locates at the Downtown Core Planning Area (Figure 4.2).

Also, there are two categories of office space – "Category 1" and "Category 2":

- "Category 1" office space refers to office space in buildings located in core business areas in Downtown Core and Orchard Planning Area which are relatively modern or recently refurbished, command relatively high rentals and have large floor plate size and gross floor area.
- "Category 2" office space refers to the remaining office space in Singapore which are not included in "Category 1".

The office space of these four towers of Central all belongs to Category 1 office.

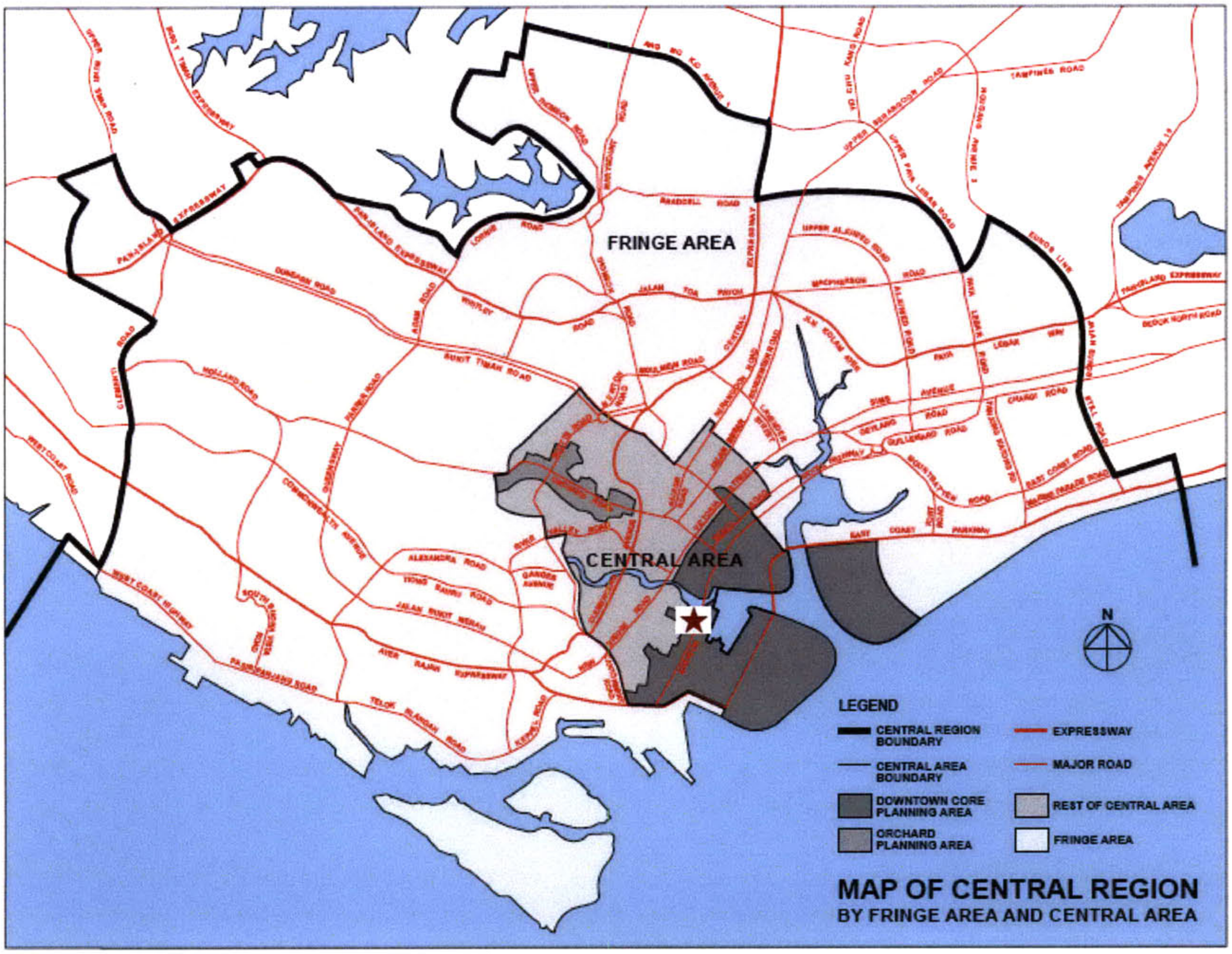


Figure 4.2: Location of Central (Source: Urban Redevelopment Authority of Singapore, 2010)

First Mover of Small Office & Home Office (SOHO) in Singapore

FEO was the first real estate developer in Singapore that introduced the concept of Small Office & Home Office (SOHO) early in 2006, right after SOHO's success and popularity in the western countries. While there are advantages to be the first mover, the unavoidable tradeoff is high risk. It is a common and usual strategy dilemma facing by real estate developers.

Figure 4.3: Inside of Central (Top left – SOHO 1; Top right – Separate Elevator System; Bottom right – Garden on the Podium Roof; Bottom left – Podium Shopping Mall. Source: Author)

The table below shows the key development information of Central.

Table 4.1: Property Characteristic of Central

Project Name	*Central*				
Developer	Far East Organization				
Architect	Jerry Chan (Department Architect at FEO)				
Location	6 Eu Tong Sen Street Singapore 059817 Above Clarke Quay MRT station and next to Singapore River, CBD				
Site Area	13,853.1 m^2				
Plot Ratio	5.6				
Max Gross Floor Area[7] (GFA)	77577.36 m^2				
No. of Car parks Lots	377				
Award	Cityscape Asia Real Estate Award, 2009				
Structure	Podium	Office	Studio Office	SOHO 1	SOHO 2
Stories	5 (L1-L5)	15 (L11-L25)	15 (L11-L25)	8 (L5-L12)	5 (L4-L8)
Phases	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Land Cost	S$340,800,000				
Construction Cost	S$170,000,000				

The overall development timeline of Central is summarized below:

- 24/11/2006 – Shopping podium from basement to 5th floor excluding part 1st floor retail around the train station entrance.
- 29/12/2006 – 6th floor car park only
- 28/02/2007 – 1st floor area including and around retail units
- 04/04/2007 – Car park at 7th to 9th floor and remaining 1st floor retail units
- End of 2007 – SOHO1 and SOHO2
- 08/05/2008 – Regular office tower and New Age Office tower.

[7] Gross Floor Area, GFA, is the total area of all floors in a building on a lot, measured to the extreme outer limits of each building.

4.2 Option Valuation Using the Engineering-Based Approach

Kalligeros and de Neufville (2006) established a real option valuation model based on Monte Carlo Simulation and propose to apply it in certain classes of engineering systems for the purpose of design. They described their valuation scheme along four dimensions: state-space modeling, uncertainty modeling, decision rules and valuation. Their options evaluation process contains five steps:

(1) Define one or more operational states, i.e., alternative designs of the system. An operational state may include reversible flexibility. Estimate free cash flows as a function of time, the design variables and the uncertainties for each operational state. The entire organization can only be in a single operational state at a time.
(2) Uncertainty simulation.
(3) Value one "representative" operational state using established valuation processes for each path of simulated uncertainties.
(4) Value all other operational states using a discount rate adjusted for the relative risk between each operational state and the representative operational state.
(5) Value all timing and choice options to transition between operational states and the same way. The value of flexibility in each operational state is the sum of the intrinsic value of that state and the value of its options.

They conclude that the above process is general and can be applied to a variety of technical systems, even though it is more suitable for certain types of situations. Recall the advantages of this engineering-based option valuation approach discussed in Chapter 1, this thesis will apply this approach the case study.

The main structure of real options analysis process of the Central is formed the following steps:

(1) Define the assumptions of the overall model.
(2) Identify and model major uncertainties involved in the case.
(3) Apply option-thinking and define the decision making structure for the flexible case.
(4) Monte Carlo simulation and scenarios comparison;

a) Shopping podium and two office towers (SOHO1 and SOHO2).
b) Shopping podium and four office towers (regular office, New Age office, SOHO1, and SOHO2).
c) Shopping podium and two office towers, SOHO1 and SOHO2, plus vertical expansion option of two more office towers in the future.

(5) Interpret the results using the Value at Risk and Gain (VARG) curve.

4.2.1 Assumptions

Assumptions of the real options analysis for Central include:

- The analysis is from an ex-post perspective: set the beginning of 2009 as "present" and all cash flows are discounted to this time point to get their "present value".
- Construction of scenario 1 (the podium + SOHO 1+ SOHO 2) will last for 2 years; construction of the other two office towers will last another 1 year. Construction cost of each part, shopping podium and each office tower, equals the total cost times the ratio of that part's GFA to the total GFA.
- Development cost growth rate is 1.5%.
- Project discount rate is 9%.
- Operating expenses are S$10 per square meters.
- The completion period[8] of Central is 10 years.
- All cash flows occur at the end of that year.
- Land cost occurs at the beginning of 2009.

4.2.2 Identify and Model Major Uncertainties

Uncertainty of Rent in Space Market

Estimating the current and future market rent levels applicable to the space in the subject is crucial to property valuation because of the fact that much of the potential gross income (PGI) projection, especially in future years, is derived from the market rent level projection (Geltner et

[8] The completion period is set by Urban Redevelopment Authority of Singapore. The whole proposed development of Central must be completed within this period.

al, 2007). Although we cannot predict the relevant future rent level with anything like perfect, forecasts need to be realistic and unbiased. There are mainly six different sources/types of uncertainties in the valuation of real estate underlying assets: ***initial rent, trend (annual growth rate), annual volatility, cycle, current noise, capitalization rate.***

Rent Forecasting Methodology[9]

The Initial Rent is the rent (of office space or shop space) at the time when the construction is completed. Since we assume we are NOW at the beginning of construction, we know the rent now and it will evolve during the construction period.

Trend here represents the annual growth rate of the rent. Volatility is refers to the annual volatility of the rent annual growth rate. Estimates of both annul rent growth rate and volatility can be extracted from historical data of local space market, as shown in Chapter 2. The volatility has an additional component to reflect idiosyncratic risk. This could be an independent accumulating random walk component additive to the market volatility, with a standard deviation of around 10% per year. Or we could just model the entire volatility (market + idiosyncratic) for a typical individual property as around 15% to 20% per year instead. This thesis uses the former method.

The cycle component, including amplitude, period, and the phase, can be estimated using a long-term (such as 40 years) history of commercial property prices. For Central, the Real Estate Information System[10] (REALIS) of Singapore provides historical rent information of both office and shop space in the long term (Figure 4.4 and 4.5).

As for the noise component (both initial and current), there is evidence (Geltner, et al, 2007) that a typical standard deviation would be 10% to 15%, which does not accumulate over time like the volatility does.

[9] More detailed rent forecasting methodology and spreadsheets are in Appendix C.
[10] Website of REALIS: https://spring.ura.gov.sg/lad/ore/login/index.cfm

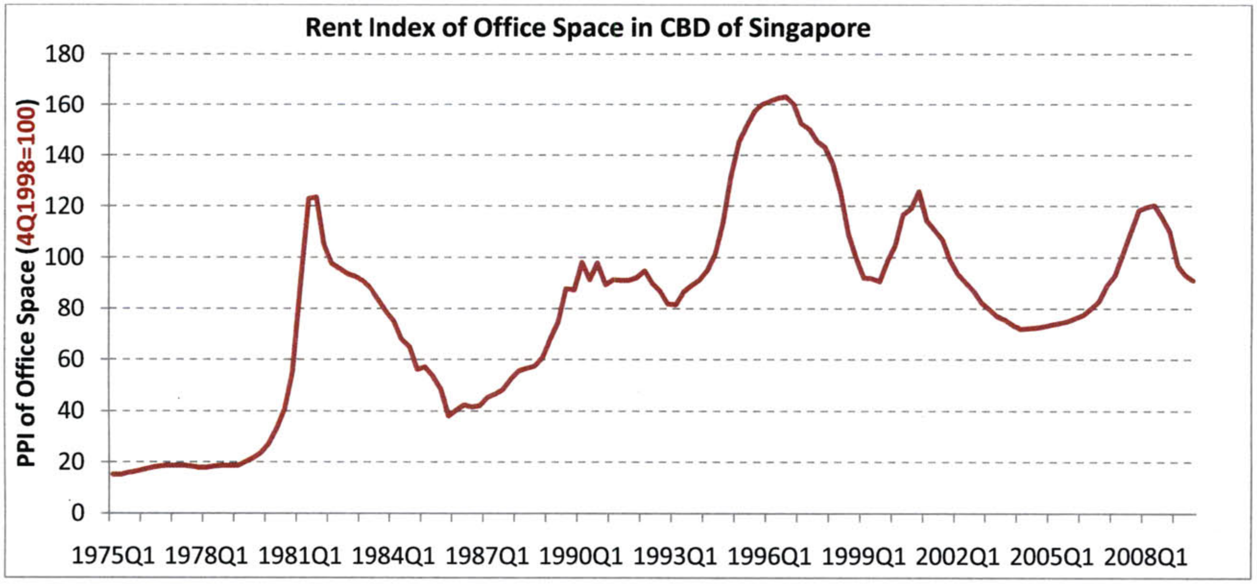


Figure 4.4: Long Term Historical Office Space Rent Index in CBD of Singapore

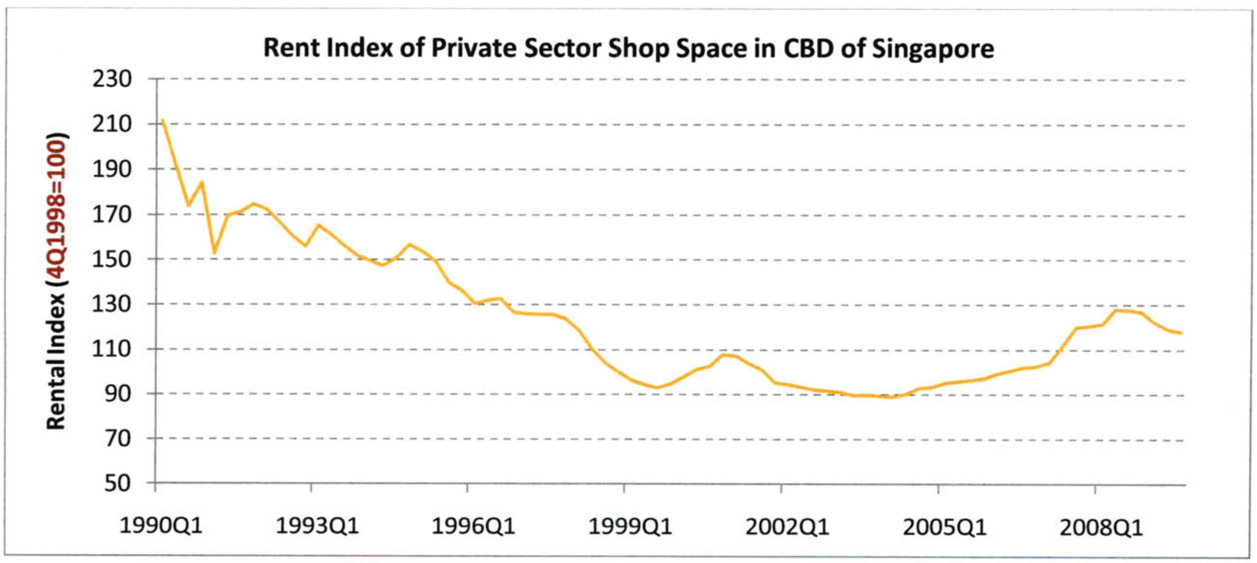


Figure 4.5: Long Term Historical Rent Index of Shop Space in CBD of Singapore

Figure 4.6 and Figure 4.7 are examples of forecasting the rent index of shop space at CBD and Category 1 office space in Singapore by considering uncertainties of initial rent (rent in 2010), annual growth rate (8% for office space, 2.6% for shop space), annual volatility (25.6% for office space, 8.5% for shop space), cycle (9 years for office, space, 7 years for shop space) and current noise (15% for both office space and shop space).

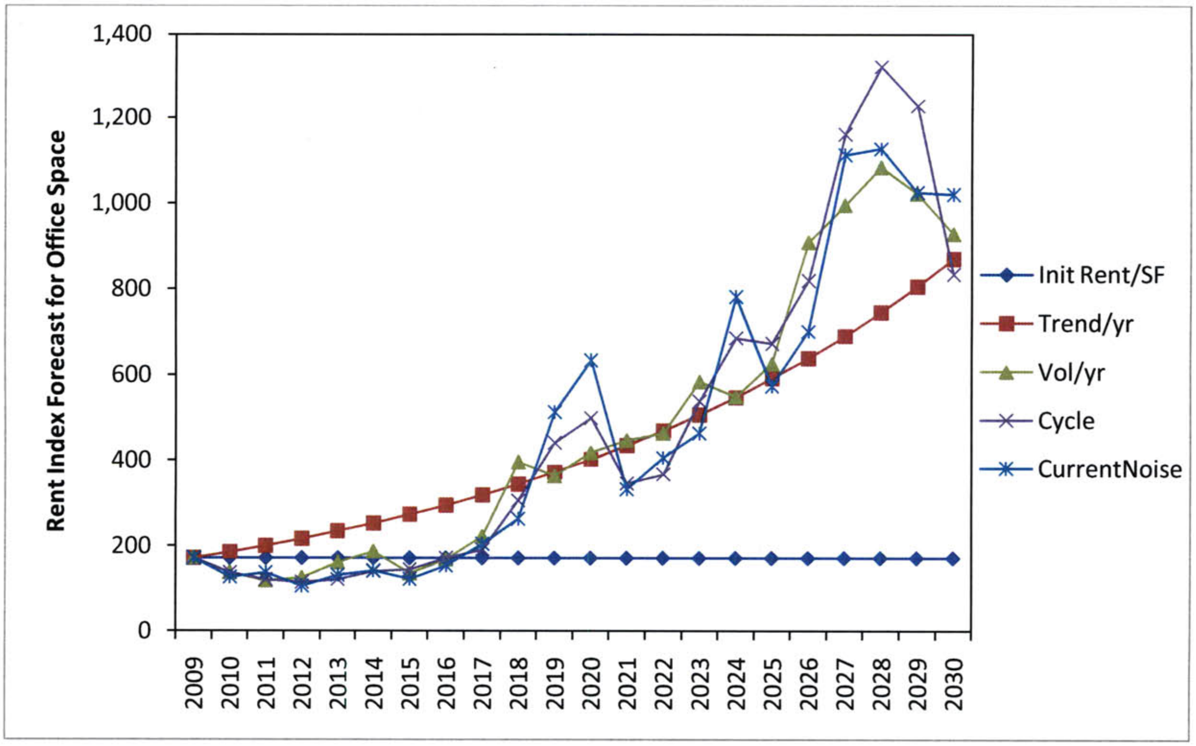


Figure 4.6: Example of a Possible Office Space Rent Forecast

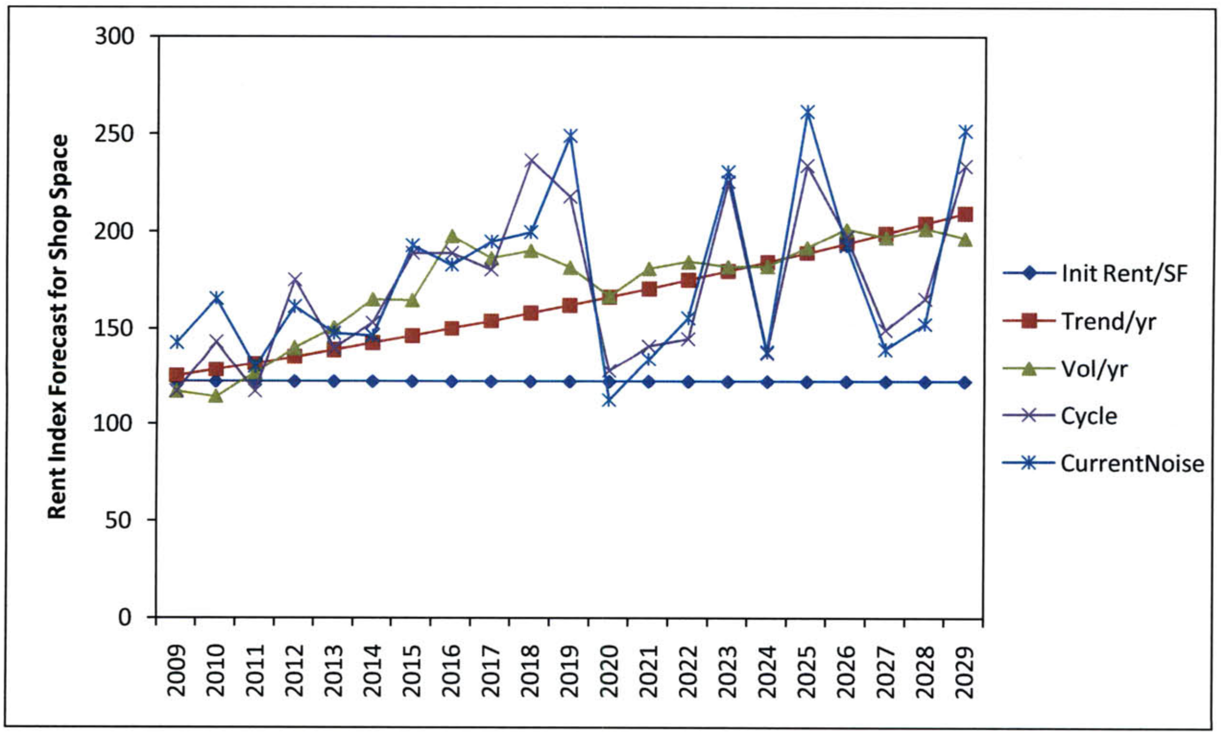


Figure 4.7: Example of a Possible Shop Space Rent Index Forecast

Uncertainty of Lease-up Rate

The second source of uncertainty is the expected lease up rate of both the office space and shop space. This simulated lease-up is based on leasing all of the potential space in the development over time (Guma, 2008). The first year lease-up rate is generated from a triangular distribution, which can range from 30% to 60% of the entire potential space[11] considering that the shopping podium plus SOHO1 and SOHO2 together is about 58.2% of the total. Each subsequent year lease-up rate can range from zero to a maximum amount that falls between 25% and 65% of the total remaining available space of that year. The following shows a possible lease-up scenario of entire potential space of Central from 2012[12] to 2030.

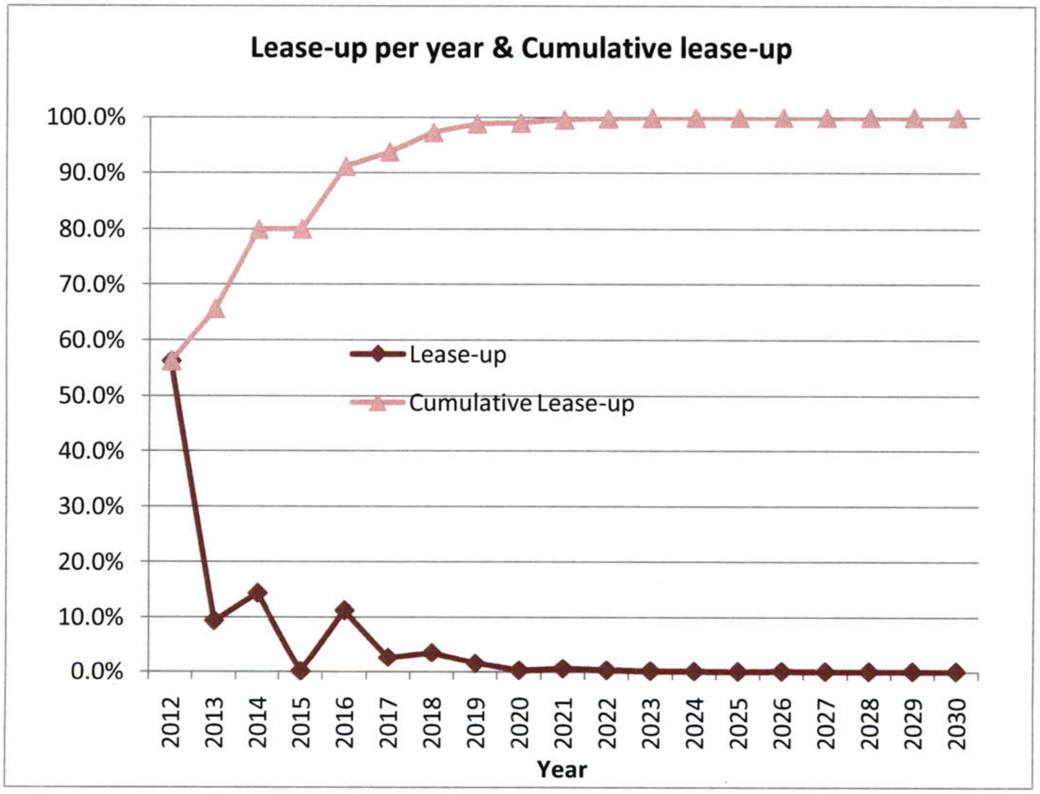


Figure 4.8: Example of a Possible Lease-up Scenario of Central

Policies of Authorities (Zoning, Building codes, Environmental Requirement)

These uncertainties come from relevant government authorities' policy evolution. Take "green building" as an example, Building industry is already the third-largest contributor to Singapore's

[11] The entire potential space is the total GFA of the shopping podium, SOHO1, SOHO2, regular office, and New Age office.

[12] Since the construction of Scenario 1 is completed in 2012

carbon emissions after the manufacturing and transport sectors. Actually, the concept of green building or green design is not new and it can date back to early sixties. Recently, the global climate change challenge makes green buildings much more attractive in many countries including Singapore. For example, office building of City Developments, which won a Green Mark award for its environmental performance, was cited as the an example of sustainable construction. National Development Minister of Singapore Mah Bow Tan pointed out that green building practices may be mandated in the future. However, the construction cost of green building is still comparably much higher than regular building, which impedes its wider application of developers. To prosper, developers must stay ahead of change and be prepared. A "Green Option" can make the developers be better positioned to cope with this challenge, especially for the later phase to be built in the future.

Interactions of Uncertainties

More often than not, different uncertain factors are correlated to certain extent, while some may be highly correlated (either positive or negative). Specifically, both experiences and historical data show strong evidence that rent and lease-up are always positively correlated to each other. Other uncertain fact, such as construction cost, it may be comparably more stable than rent and are influenced by the macro economic conditions. Government zoning policies can influence the property price. Take a land parcel zoned for commercial use for example, if the government zones the area next to this site as a park or core transportation station, this could probably increase the property price or rent since it makes easier to access potential customers. How big the influence is of course depends on specific case. Besides, from macro economic perspective, government policies can influence the local real estate market on a macro level. Again, we can look at the case of Singapore. The government's long-term strategy to develop Singapore as a shopping center for South Asia contributed to many developments of large-size and high quality shopping malls at CBD; Central is one of them. This kind of uncertainty is mostly information-driven and typically hard to model and simulate.

4.2.3 Option-thinking and Option Decision Rule

Phasing Option of Office Towers

We consider a stage development option by comparing three different scenarios of development:

(1) The developer builds only the shopping podium and the two office towers, SOHO 1 and SOHO2. The building cannot be expanded vertically in the future.

(2) The developer builds the shopping podium and four office towers all at once.

(3) The developer builds the shopping podium and two office towers, SOHO1 and SOHO2, at the beginning. The building can build another two office towers in the future.

By comparing scenarios, we can calculate the option value of vertical phasing of Central.

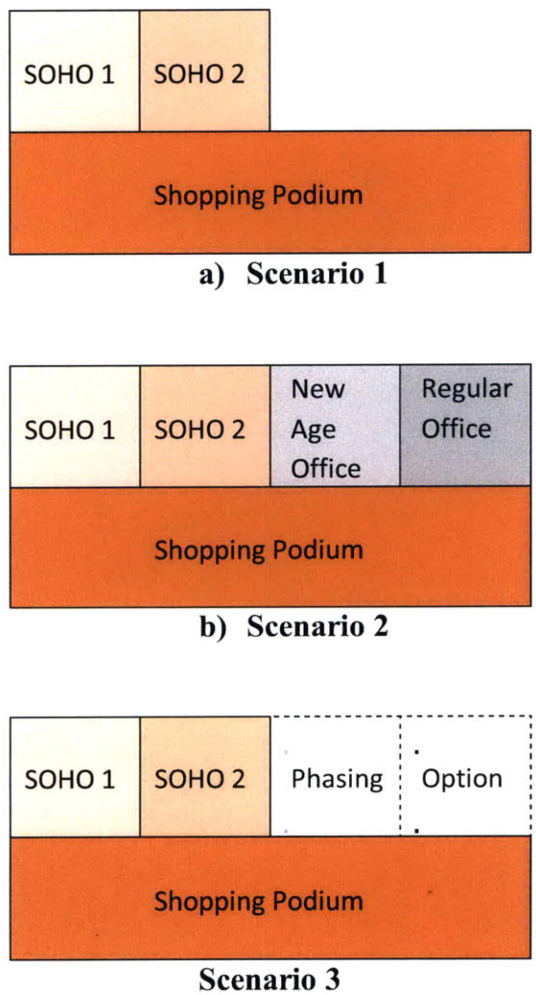


Figure 4.9: Conceptual Models of Three Different Scenarios of Central

Option Decision Rule

Regarding the uncertain factor we indentified, the option decision to expand the building vertically by adding two office towers in Scenario 3 can be based on two perspectives: rent growth rate and lease-up rate.

- The lease-up rate is the simulated using the methodology outlined in previous section. The model will check the lease-up rate every year to see whether it meet the hurdle rate the developer set. This thesis uses 70% as the hurdle rate of potential lease-up.
- The annual growth rate of rent of office space is calculated for each year, which model will check every year. The hurdle rate of rent growth can be based on the historical data and the current macro market conditions. The developer can leverage it by its expertise of and insights of the real estate's long term performance. This thesis uses 5% as the hurdle rate.

The first year that meets both criteria will trigger the exercise of vertical expansion options of the office towers. It is worthy to note that the decision rule applied here does not need to be the most "perfect" one[13]. Potential work will include the sensitivity analysis of option decision rules as indicated previously in Chapter 3.

4.2.4 Monte Carlo Simulation and Scenario Comparison

Cash Flows Calculation in Monte Carlo Simulation

The property-before-tax cash flow (PBTCF) provides a realistic picture of the free-and-clear cash flow available to the owners of the property (before debt service and income taxes are taken out). Potential Gross Income is the cash the building could earn if it were fully rented. Capitalization rate is the ratio between the net operating income produced by an asset and its capital cost (the original price paid to buy the asset) or alternatively its current market value. The vacancy allowance accounts for the expected effect of vacancy in the net cash flow of the property. Operating expenses (OE) include a number of regular occurring, specific expense line items associated with the ongoing operation of the property. There are two major operating expense

[13] By "perfect", it be judged by different criteria; a typical interpretation is the highest expected NPV of the project. It can vary depending on the developer's other objectives.

categories: (1) largely fixed costs that are insensitive to the occupancy level, including property taxes, hazard insurance, property security, property management; (2) largely variable costs that are sensitive to occupancy level, including utilities, building and grounds maintenance and routine repairs.

Table 4.2: Typical Line Items in a Proforma for Income Property (Adopted from Geltner et al, 2007)

Operating (all years):		
Potential gross income (PGI) = (Rent/SF) × (Rentable SF) =		PGI
- Vacancy allowance = - (Vacancy Rate) × (PGI) =	-	v
+ Other Income (e.g., parking, laundry) =	+	OI
- Operating expenses =	-	OE
Net operating income =		NOI
- Capital improvement expenditures =	-	CI
Property-before-tax cash flow =		PBTCF

To simplify the case, we only consider the rent income (assume no other income); and we also do not consider the capital improvement expenditures. Table 4.3 shows an example of the cash flows calculation of scenario during one simulation. Spreadsheets of NPV calculation of all scenarios are listed in the Appendix.

Table 4.3: NPV Calculation in Monte Carlo Simulation

NPV Calculation							
Year	Beginning of 2010	2010	2011	2012	...	2029	2030
	0	1	2	3	...	20	21
Development Costs (S$ M)	340.8	65.3	33.7				
Rental Income (S$ M)		0.0	0.0	37.8	...	1.3	0.0
Operating Costs (S$ million)		0.0	0.0	0.3	...	0.2	0.2
Income Before Income Taxes (S$ M)	-340.8	-65.3	-33.7	37.5	...	1.1	-0.1
Tax Shields from Debt Finance							
Discounted Cash Flows (S$ M)	-340.8	-59.9	-28.4	29.0	...	0.2	0.0
NPV (S$ M)	-309.9						

Outline of Monte Carlo Simulation Process

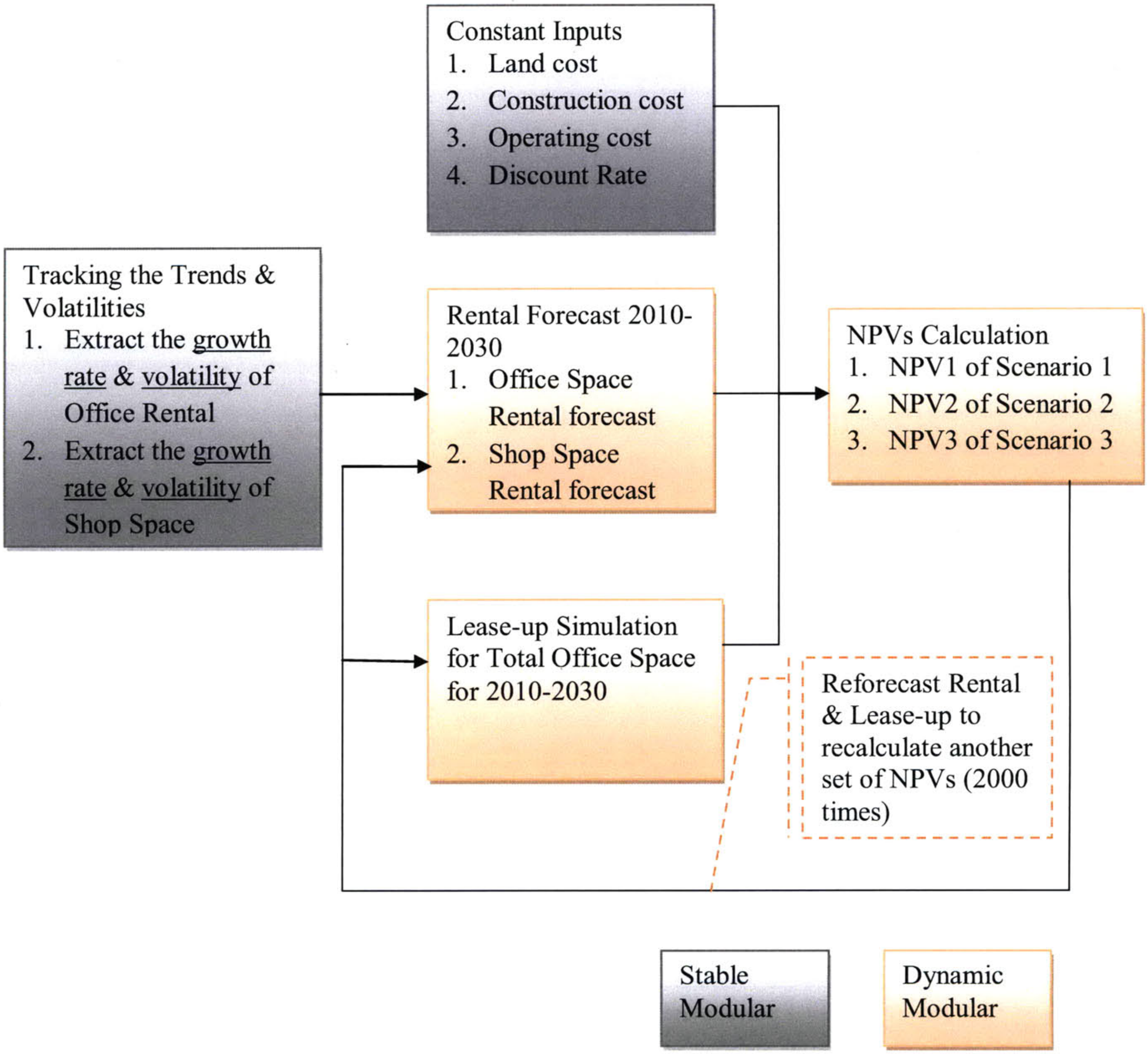


Figure 4.10: Data flow in Monte Carlo Simulation of Central

All stable inputs in the simulation process are listed in the following table.

Table 4.4: Stable Inputs in Monte Carlo Simulation for Three Scenarios

Gross Floor Area Total (m^2)		77577	100.0%	**Net Floor Area (m^2)**	
	Shopping Podium	29783	38.4%		18663
	SOHO 1 (8 stories)	11090	14.3%		9256
	SOHO 2 (5 stories)	4293	5.5%	58.2%	3243
	Studio Office (15 stories)	11306	14.6%		8370
	Regular Office	21106	27.2%	41.8%	16514
Total Office Space		47794.71			
(SOHO 1 + SOHO 2)/Total Office Space			32.2%		
Land Cost (S$)		340,800,000			
Total Construction Costs (S$)		170,000,000			
	Shopping Podium	65,264,537			
	SOHO 1	24,302,916			
	SOHO 2	9,407,688	98,975,142		
	Studio Office	24,774,475			
	Regular Office	46,250,383	71,024,858		
Construction Costs Growth (annual)		1%			
Operating Costs (S$/$m^2$)		10			
Project Discount Rate		9%			

Interpret Results Using Value at Risk and Gain (VARG)/Target Curve

The simulation results are summarized in the Table 4.5.

Table 4.5: Simulation Results

S$ Million	**S1**	**S2**	**S3**
Initial Investment	439.7	510.8	439.7
Expected NPV	-5.6	306.6	278.6
Max NPV	341.3	1270.9	1306.5
Min NPV	-183.7	-139.1	-150.2
Return on Investment	-1.3%	60.0%	63.4%

It can also be shown using the Value at Risk and Gain curve/Target Curve. The Target Curve is another name for cumulative distribution function (CDF). It aims at making a representation to managers that:

- "There is a probability X that we will lose (or gain) more than Y dollars for this project"
- Provides cumulative probability of reaching a "target" value

Value at Risk (VaR) is common language on Wall Street which characterizes range of simulation outcomes and stresses downside risk. While VaR is well recognized, there are also opportunities for gain – Value at Gain. de Neufville (2006) pioneered the concept of Value at Risk and Gain, which can show the real option analysis results very clear.

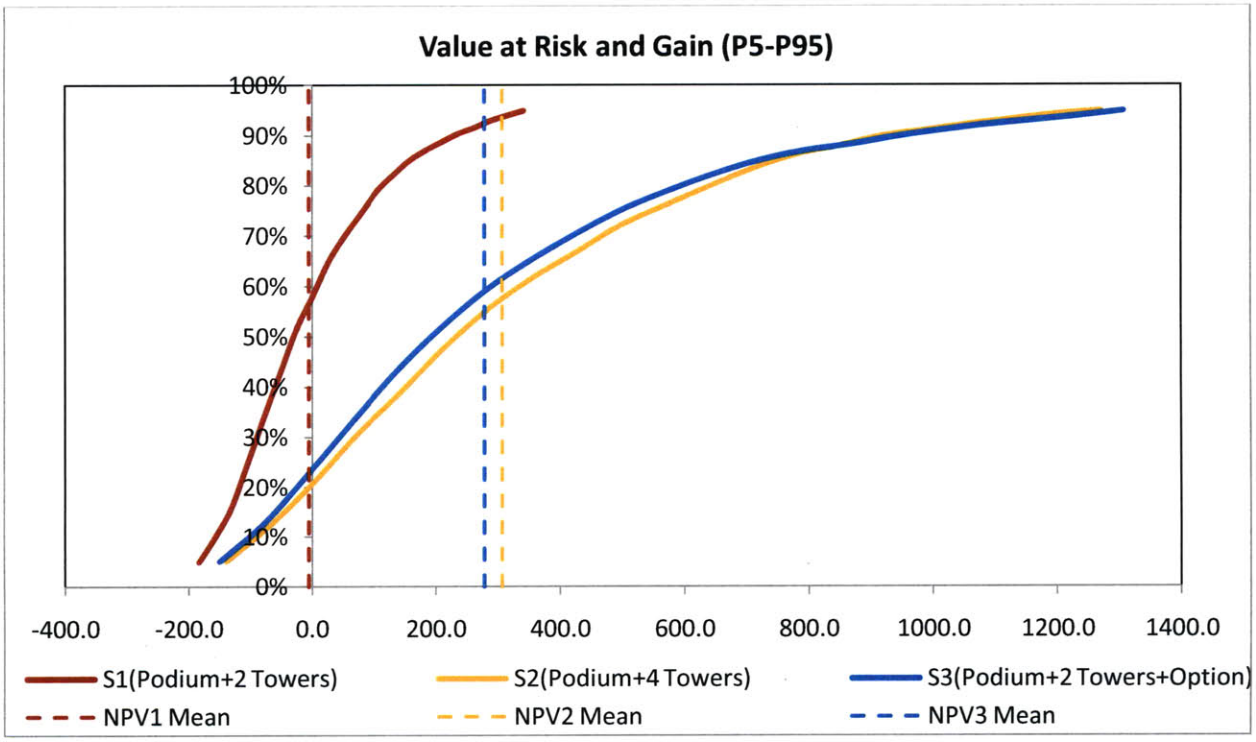
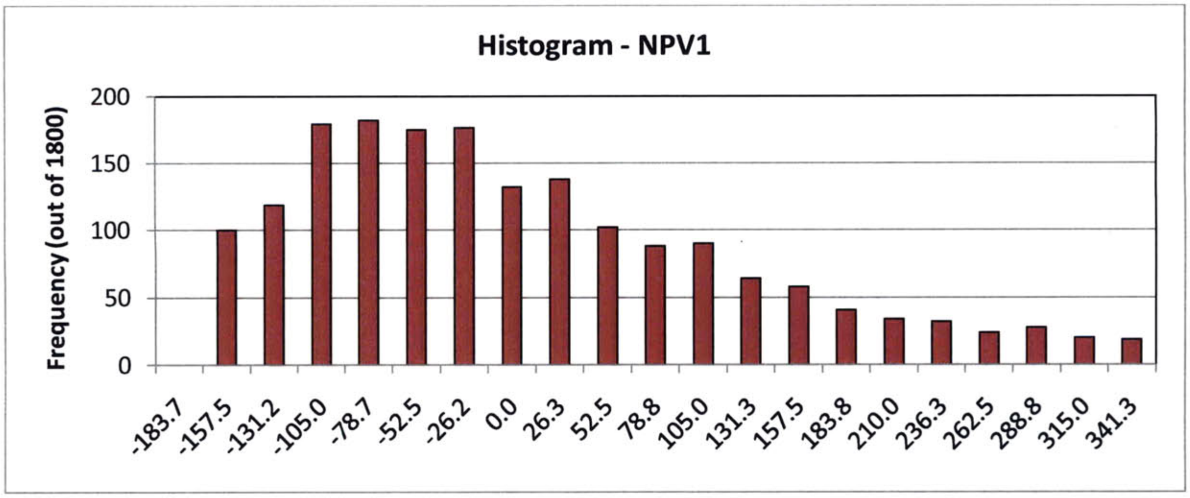
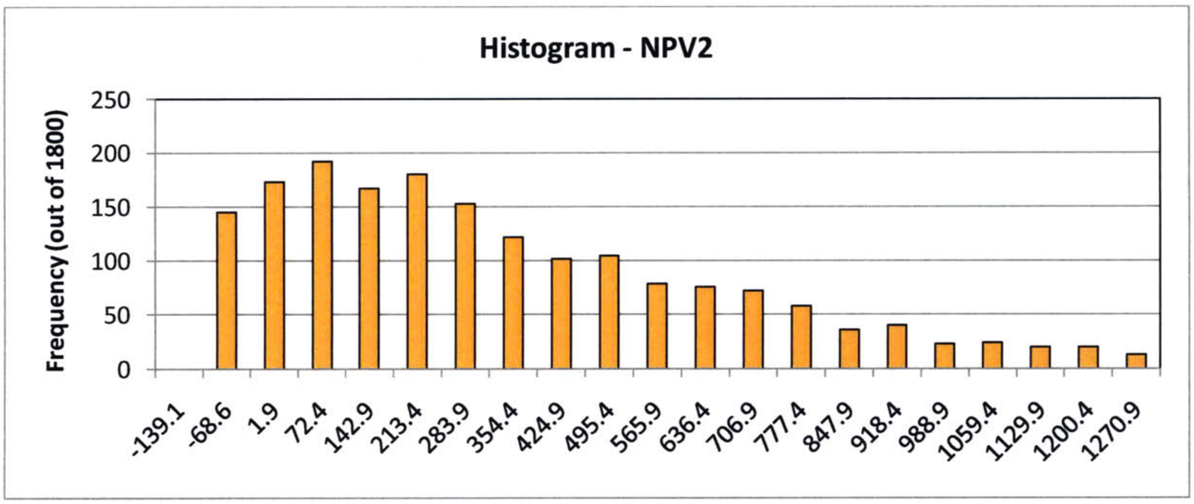


Figure 4.11: Value at Risk and Gain Curve of Central

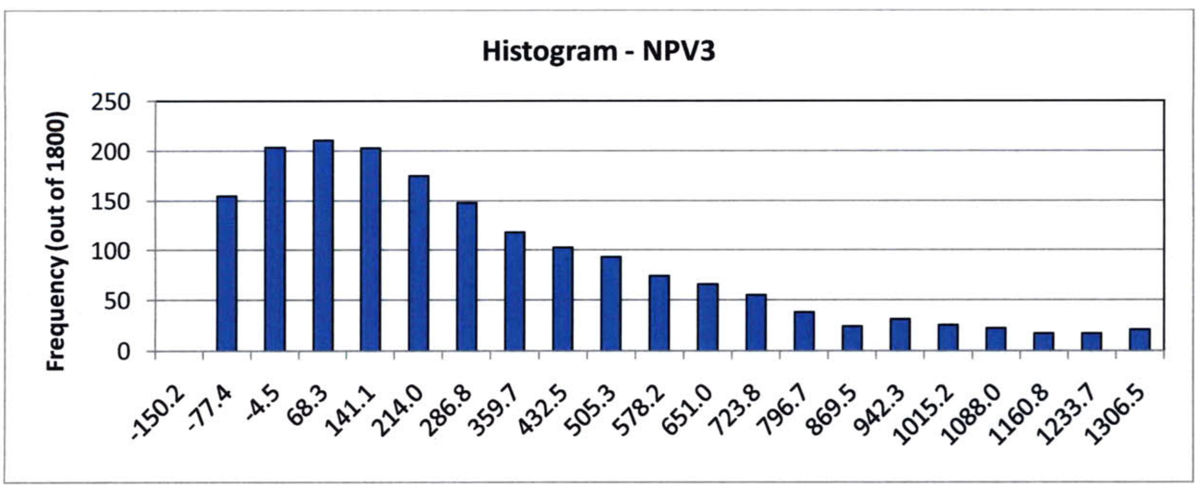
The VARG curve (Figure 4.11) clearly shows that the flexible case can significantly increase the expected NPV compared to the inflexible scenario 1, since the expansion option is exercised under good market conditions. Having comparable performance with scenario 2, the initial investment of the flexible scenario 3 is much less than the former. The histograms in Figure 4.12 show the distribution of NPVs for these three scenarios.



a)



b)



c)

Figure 4.12: Histograms of NPV1, NPV2, and NPV3

Future work could look at many other scenarios, for example, Podium + 3 Towers + Expansion Option. The three towers can be New Age Office, Regular Office, and one SOHO, let the second SOHO tower as an option. The first SOHO tower can be used as a test of water since FEO was the first mover to bring this concept to Singapore. If the market response is good enough, the option of the second tower will be exercised at appropriate time.

4.3 Sensitivity Analysis

Although incorporating flexibility into real estate development can have positive value implications on the expected value of the development, the outcome of flexibility is sensitive many factors especially some key inputs that representing the uncertainties of the market. In the meantime, estimates of these parameters can vary from developer to developer. As outlined previously in Chapter 3, sensitivity analysis of key inputs should always accompany real options valuation.

Trends and volatilities of office rent in previous simulation are estimated from data series between 2000 Quarter 1 to 2009 Quarter 3. In this section, the trend and volatility estimates of office rent is based on 1990 Quarter 1 to 2009 Quarter 3, while those of shop rent are based on 1991 Quarter 1 to 2009 Quarter 3. These estimates represent a downward real estate market trend with high volatility. Also, for the lease-up simulation, the first year lease-up is set to range from 20% to 50% (previous simulation using 30% to 60%).

Table 4.6: Different Estimates of Office Rent Trends and Volatilities

	Category 1 Office Space	
Time Series	Standard Deviation	Annual Growth Rate
90Q1-09Q3	24.96%	0.57%
00Q1-09Q3	25.63%	8.04%
04Q1-09Q3	15.65%	23.29%

Table 4.7: Different Estimates of Shop Rent Trends and Volatilities

	Shop Space at CBD	
Time Series	Standard Deviation	Annual Growth Rates
91Q1-09Q3	15.373%	-2.9%
00Q1-09Q3	8.520%	2.6%

Then, we do the Monte Carlo simulation again using these new inputs; the results are shown in the new VAGR curve and histograms of NPVs. Based on the new results, the developer not only need to reconsider the flexibility value, but also whether to go with the project at all. In practice, the developer can try many different combinations of the key inputs they feel comfortable in order to assess the Option Value Interval. This range of option value can used to assist investment decision-making.

Table 4.8: Simulation Results Using New Inputs

S$ Million	S1	S2	S3
Initial Investment	439 .7	510.8	439.7
Expected NPV	-199.5	-88.2	-117.0
Max NPV	-14.3	399.3	317.1
Min NPV	-309.1	-314.0	-316.3
Return on Investment	-45.4%	-17.3%	-26.6%

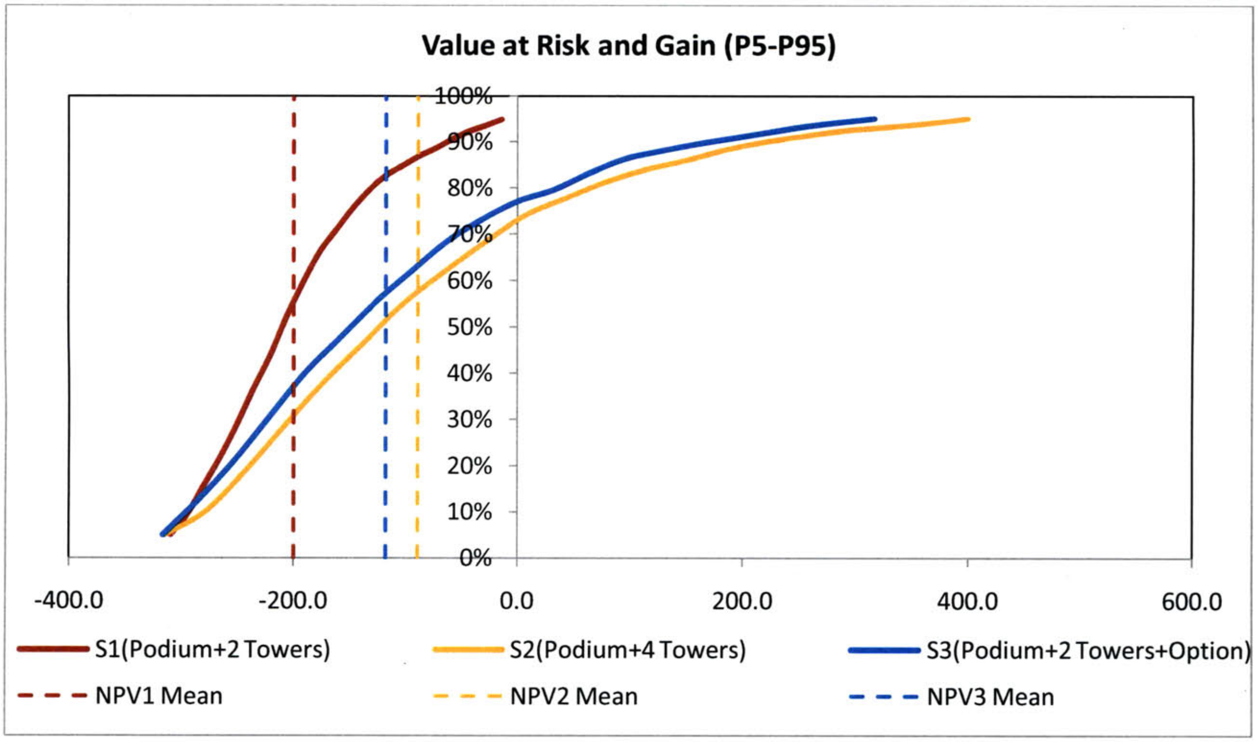
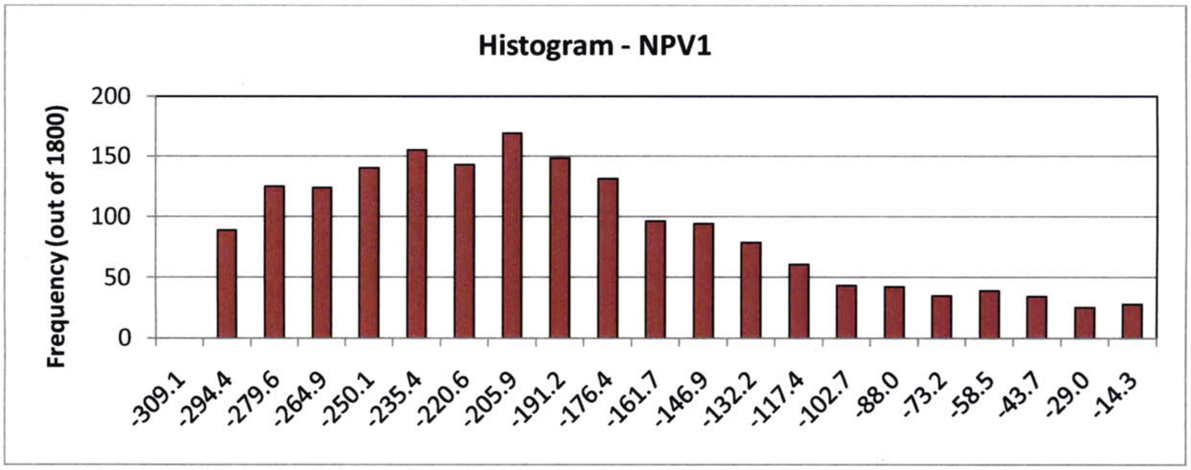
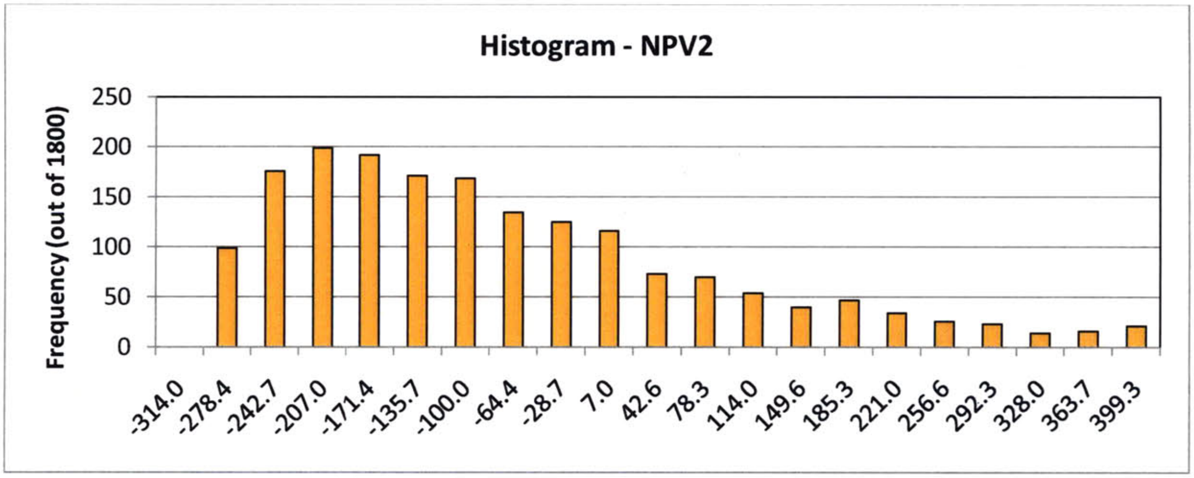


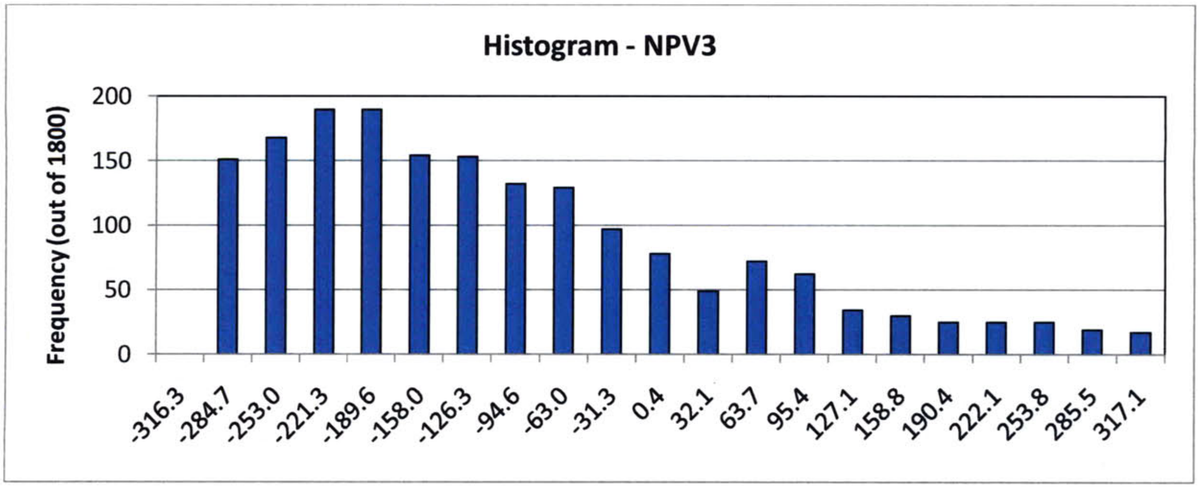
Figure 4.13: VARG curve of Central Using Different Inputs



a) Histogram of NPV1



b) Histogram of NPV2



c) Histogram of NPV3

Figure 4.14: Histograms of NPV1, NPV2, NPV3 Using Different Inputs

4.4 Lessons from the Case Study

A very unique thing about this case is the high ratio of the land cost to construction cost, which is very unusual. Due to the perfect location of Central, the land cost of this project is almost twice the cost of its construction. According to an interview with the Director of FEO, high land cost is a big motivation for the developer to build more at the beginning in order to get rent income as early (and hopefully as much as possible) as possible to recovery the initial cost of the land. Based on this intuition, the construction of Central was continuously not phased. After the completion of the shopping podium, the four office towers were built simultaneously (Figure 4.15). This fact indicates that vertical expansion option may be more attractive to the developers in volatile market if they can buy the land cost at cheap price.

Figure 4.15: Central under construction

Advantages of Phased Development

Vertical expansion enables the commercial real estate developers to adjust their offers to the market. Therefore, they have the ability to get rid of downside losses well as to take advantage of potential upside opportunities.

Mitigate Market Risk

Market risk is a significant risk inherent in the development process. Vertical phasing can potentially enable a developer to manage initial lease-up risk more effectively by allowing a building to grow as market conditions warrant. With the flexibility of vertical phasing, when the market conditions change, a developer can quickly and more effectively capture market demand without further permitting and subsurface risk. Market conditions, and specially lack of demand, will be a central driver of the application of vertical phasing option.

Financial Benefits

The financial benefits due to delay of initial cash spending can be clearly verified by real options analysis, which will be carried out in the following work.

Avoid Subsurface Risk

One of the riskiest and most unpredictable parts of a construction project involves subsurface conditions on the site. Even though a variety of testing can be performed to identify and mitigate potential risks, surprises can nevertheless occur. However, with vertical phasing there is no additional subsurface risk for future phases. Vertical phasing provides a clean and controlled surface on which to build, an advantage not available in horizontal phasing. Vertical expansion therefore can help avoid costs that would be incurred with a horizontal expansion. Areas that have challenging subsurface conditions may find vertical expansion to be particularly appealing, as it enables the developer to go into the ground only once.

Current Problems with Implementation

Do vertical phasing half way may be a waste of money. If we invest in the future, but don't plan for the future, there probably won't be one. There is another mix-use commercial development of the FEO "Square 2", the company only planned for extra 3 floors and they didn't do any special arrangement for this, expect the foundation and the strength of the structure can meet the requirement of a total 14 floors (right now is 11). Actually, the company may have problems if they want to exercise this option. Because the utility systems (air conditioners, water tanks, etc) are typically put on the roof of the building here and they may have to move it to the 14 floors.

The problem is the 11 floors cannot use air conditioners when they build the extra 3 floors. And the arrangements of amenities are left in the air.

Change of Use

In Singapore, the government fixes the use of specific parcel of land in master plans. But the developer can apply to change the use by paying the charge for it. This charge of course contributes to the cost of the flexibility. Typically, it is very hard to incorporate the flexibility of changing from residential to commercial; one of the reasons is the latter requires bigger weight load strength.

CHAPTER 5: IMPLEMENTATIONS FOR FLEXIBILITY DESIGN IN INFRASTRUCTURE DEVELOPMENT

This chapter addresses the policy perspective of designing and exercising real options in practice.

5.1 Key Participants in Infrastructure Development Process

Standing from an owner/developer's standpoint, we discuss how to make sure the owner has the right to exercise the real options when desirable on operational level (the focus here is not the design that make the real options technically feasible to exercise but the secure the right of exercising the real options at the optimal time). In most situations, the owner can do this by forming contracts with three parties:

- Local Authorities: in charge of zoning, permitting, building codes, etc.
- Project Delivery Party: the contract of this section depends on the type of project delivery method chosen; there are currently five project delivery models – design-build (DB), design-bid-build (DBB), multi-prime, construction manager at risk, and integrated project delivery (IPD) (AIA[14] National and AIA California Council, 2007). We review the frameworks for them in the next section.
- Tenant(s): for a commercial property, such as office, shopping, the owner/developer may plan to rent the whole or part of the building. In such situation, the owner may need agreements from the tenant(s) in order to exercise the options depending on the relevant local statutes.

Obviously, it is the owner (especially when the owner is the major or only tenant of the building) who has the incentives to build appropriate real options into a development. Therefore, the burden falls on the owner to form relevant contracts with the other three parties regarding the proposed real options (see Figure 5.1). The next section shows how the owner can do this by creating: owner-project delivery party contract, owner-local authority contract, and owner-tenants contract.

[14] The American Institute of Architects

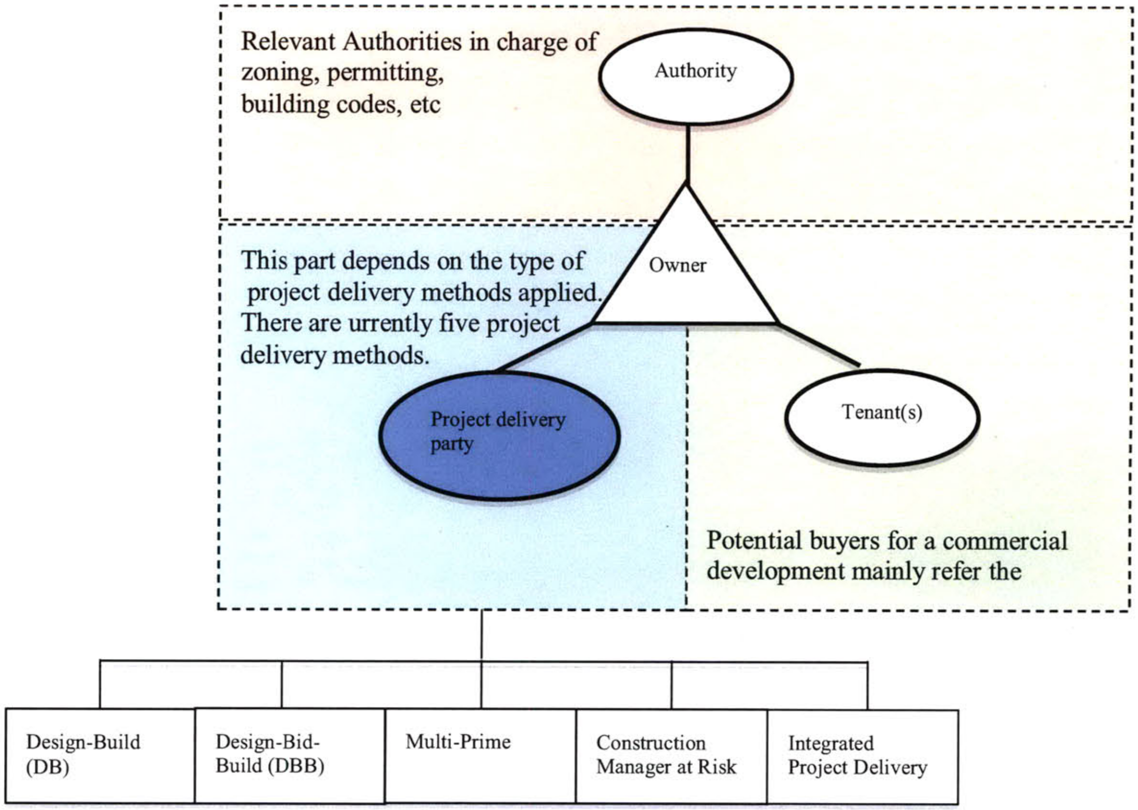


Figure 5.1: Multi-Party Contracts (MPC) in a commercial property development

5.2 Owner-Project Delivery Party Contract

The contracts between owner and the project delivery party are the most important as well as most complicated section compared to the rest during a commercial property development process. Among the five types of project delivery methods, Design-Build (DB), Design-Bid-Build (DBB), Multi-Prime, Construction Manager at Risk, and Integrated Project Delivery (IPD), DBB is currently the most prevalent one in United States, while IPD is a pioneering new model co-developed by American Institute of Architecture National and California Council in 2007, which aims to overcome the inefficiency problem of construction industry.

This section first analyzes the origins of the inefficiency of the construction industry (this is the motivation of the IPD model); and discuss how the long-term relationship between owners and contractors helps to mitigate this inefficiency issue; then we have an overview the five project delivery models and show potential challenges of incorporating real options in the development imposed by each delivery model, and how to overcome them.

5.2.1 Inefficient Construction Industry Featured of Mutable-Cost Contract

The construction Industry is an important section of almost every economy around the world. For example, in United States, its contribution to the GDP from 1959 to 1999 has remained steady just below 5% in comparison to most other private economic sectors. In 2000, it was 4.7% and not much has changed in recent years (Lepatner, 2007). However, this industry is highly fragmented and notorious for overbudget for construction cost as well as overdue for promised schedule. Lepatner (2007) analyzed the origins for this and showed some recent examples:

- The Big Dig: it was an ambitious underground highway system in downtown Boston. This project was $12 billion over budget and years late. The Boston Globe's yearlong investigation found that over $1 billion of waste was caused by errors committed by the project's managers.
- The Headquarters of Metropolitan Transit Authority: This organization built its headquarters at Two Broadway in Manhattan. This project was $300 million over budget and years late.
- Venetian Resort Hotel Casino in Las Vegas: the missed deadlines of this hotel translated into millions of dollars a day in lost casino revenue. The hotel, which finally opened in 1999 with a total cost over $1.5 billion, was one of the most costly litigations in past decades.

Lepatner argues that asymmetric information between owners and contractors and lack of effective intermediaries to mitigate are the origins of inefficient construction industry featured of mutable-cost contracts (Figure 5.2). Because asymmetric information and mutable-cost contracts put owners at a substantial disadvantage compared to builders who have every incentive to bid low on a project to the job. This is because the business is highly competitive at the bidding stage, most firms know that their low bid will not return an adequate profit. But after a contractor is awarded a contract, the situation changes radically. The contractor becomes the monopolist who attempts to recoup though change orders the profits denied it by the bidding process. Almost always, contractors find that changes in the design are necessary to get the thing built, and they subsequently charge large sums to make those changes. The contractor learns that getting the contract is the most important thing because after that he uses his superior information and market power to make the project profitable. Essentially, the contractors are incentivized to bid low to win the job, which subsequently give them the exclusive right to bid higher later. Competitive bidding is therefore no panacea because it fails to determine the final cost or quality of the job.

Mutable cost

↑

Uncompetitive market

High Level of asymmetric information + Lack of effective intermediaries = +

Weak management & small fragmented firms

↓

Low Productivity
Worker controls contractor
Dearth of education, R&D,

Figure 5.2: The Equation of Existing Industry Failure (Lepatner, 2007)

This only addresses one aspect of the problem. Actually, the motivation to form a long relationship with the owner and to establish a credible reputation, as well as the owner's expertise (such as the experienced real estate developer) makes the contractor to avoid playing the mutable-cost contract game. Specifically, almost no contractor just wants to do business with the owner only once and then quit; instead, the contractor is motivated to do honest work to secure the potential opportunity of getting the bid of following project from the owner. In this way, the contractor can form a good long-term relationship with owner. Beside, the reputation is extremely important to contractor's long-term success and profit, which further decreases the contractor's incentive to change order to increase cost. Last but not least, for experienced infrastructure developers, they developed comparable expertise from former similar projects and therefore asymmetric information has limited effect. All factors discussed above can help mitigate the inefficiency problem but cannot totally remove it. The Integrated Project Delivery (IPD) model is designed to overcome this problem as is explained in the following section.

5.2.2 Overview of Current Project Delivery Methods

We review the frameworks of the five project delivery models currently applied by practitioners (AIA National and California, 2007).

(1) Design-Build

Design-build is characterized by a single point of responsibility for both design and construction activity as Figure 5.3[15] shows. The owner often chooses Design-Build to transfer risk and coordination effort to one contractual entity and to assure a higher level of coordination. By combining both design and construction under a single entity – the design-build entity – coordination, constructability, and cost-of-change is presumed to be improved. The design-builder carries most of the risks usually in exchange for retaining some or all of any savings identified. In the meantime, it's the owner burden to be clear on the acceptable level of quality expectations through descriptive, quantitative or performance requirements in the owner's design criteria.

[15] Solid line in Figure 5.3 represent contract while dotted line refers to communication between different parties. This applies to all the figures in Chapter 5.

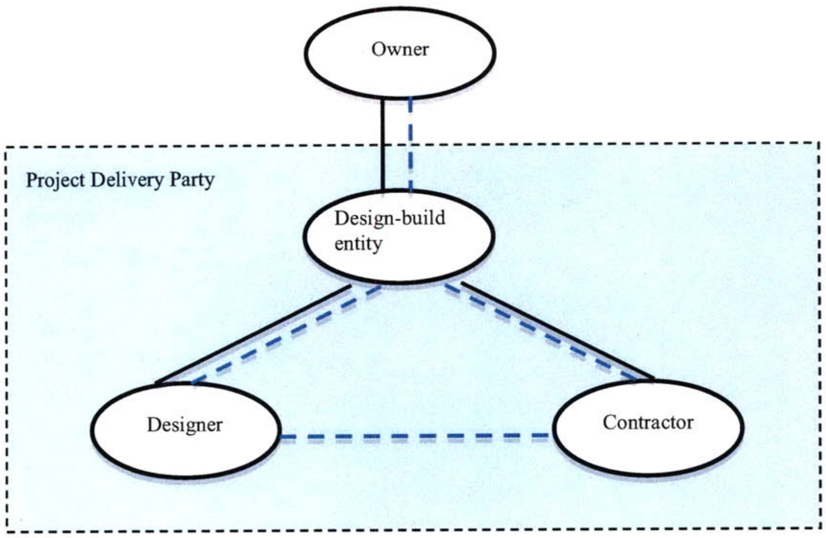


Figure 5.3: Contracts & communication among participants under design-build model (adopted from AIA National and AIA California Council, 2007)

Under this project delivery model, the owner only needs to contract and communicate with the Design-Build Entity if he/she wants to incorporate real options into the design.

(2) Design-Bid-Build

In United States' construction industry, the design-bid-build model (Figure 5.4) is currently the most prevalent delivery model since it offers the owner the market advantage of open competition through a regimented design phase followed by separate bid and construction phases. First, the owner enters a contract with the designer and they work together to develop a design meeting the owner's requirements. Then the design is put out for bid. The owner selects a contractor based on bids received and the project proceeds to construction after that. The structure of DBB does not permit early involvement of the constructor in the design process. As a result, some constructability/coordination issues cannot be discovered until construction begins.

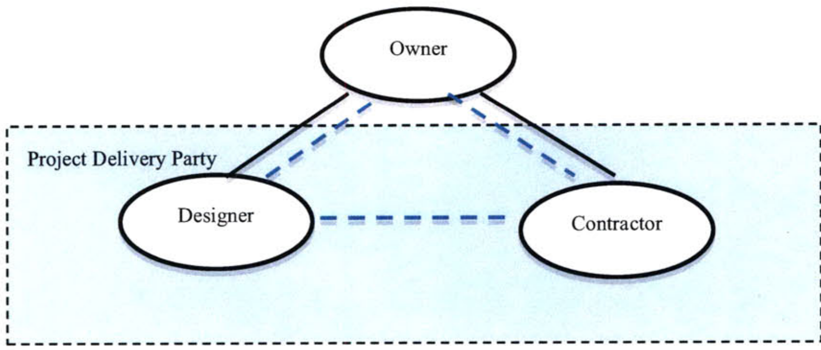


Figure 5.4: Contracts and communication among participants under DBB model (adopted from AIA National and AIA California Council, 2007)

Under DBB delivery model, if the owner plans to incorporate real options into the design, the owner not only needs to address the flexibility design to the designer in the contract, but also has to consider the cost of real options when selecting the contractor. The contractor's former experience involving similar real options can be an advantage to win the bid.

(3) Multi-Prime

In the multi-prime project delivery model, there is no general constructor. The owner acts as the general contractor and contracts directly with multiple contractors or traders to manger its own project (Figure 5.5). While this method can optimize the owner's control over the trades and reduces construction cost, it requires the owner to provide substantial management services of the various participants' effort, which accordingly requires the owner to have extensive experience and internal resources to "write individual contracts, facilitate buy out, verify and process progress payments, address and execute change orders, prepare lien releases, etc." (AIA National and AIA California Council, 2007) (Council, 2007) Obviously, most owners, except experienced real estate developers, are not able to handle all of these. Besides, multi-prime is commonly utilized within a design-bid-build process.

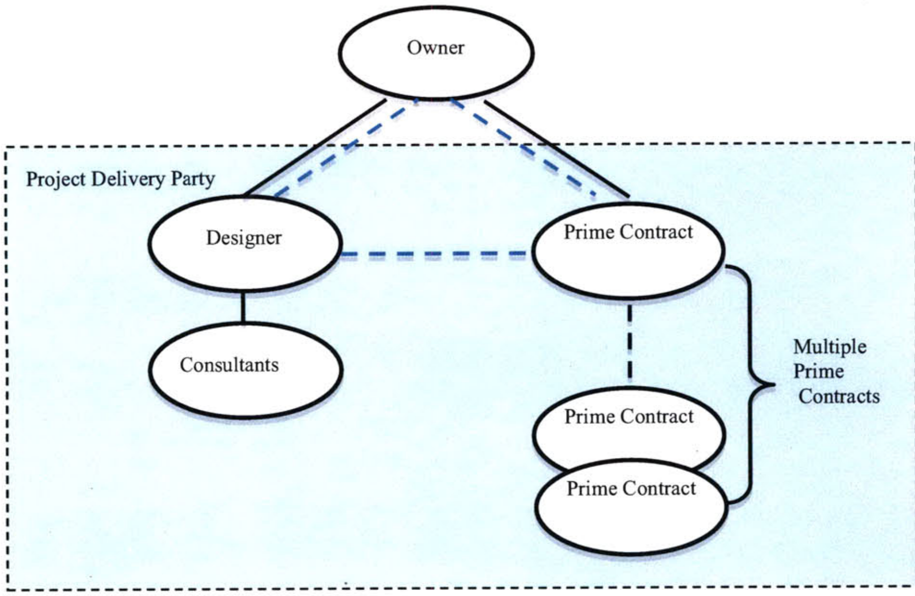


Figure 5.5: Contracts and communication among participants under Multi-Prime model (adopted from AIA National and AIA California Council, 2007)

If the owner perceives certain real options are valuable, it's comparably easier to build such real options into the building be condition of his overall control in whole process. However, in the meantime, the owner may have to form various contracts directly with both designer and each prime contractor related to the real options.

(4) Construction Manager at Risk

A construction manager is hired early in the design process to deliver an early cost commitment and to manage issues of schedule, cost, construction, and building technology. Construction Manager – Constructor (CMc) differs from Construction Manager – Adviser (CMa): CMc means the construction manager and contractor are the same one who assumes all the liability and responsibility of a general contractor, CMc is also known as Construction Manager at Risk. CMa works as an advisor and does not assume the liability as well as responsibility of the project. Like DBB, CMc offers the same direct owner-designer and owner-contractor contractual relationship (Figure 5.6). In the CMc model, the constructor is typically selected through a qualification-based selection early in the design phase and paid a fee for services performed in this phase.

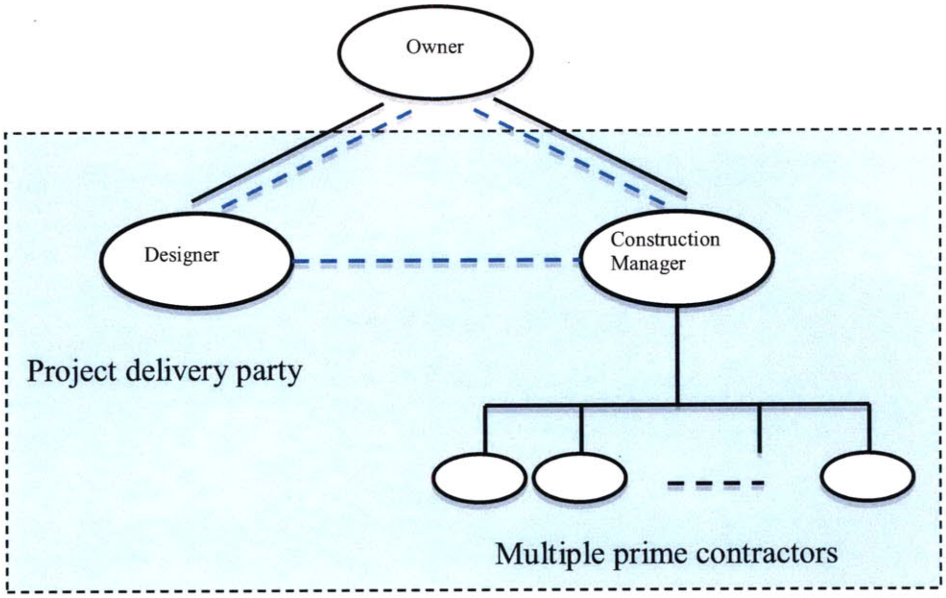


Figure 5.6: Contracts and communication among participants under CMc model (adopted from AIA National and AIA California Council, 2007)

If we only consider about incorporating real options into design, the CMc model actually is quite similar to the DBB model. An ideal construction manager would be one who has relevant experience in flexibility design and is familiar with potential issues may arise from the construction process.

(5) Integrated Project Delivery (IPD)

In 2007, the American Institute of Architecture coined the concept of Integrated Project Delivery aiming to achieve better, faster, less costly and less adversarial construction projects. IPD is "a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of al participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiently through all phases of design, fabrication, and construction." According to AIA, IPD is defined by the following characteristics:

- Early involvement of key participants (owner, architect, and builder who enters into the primary contract as well as design consultants and subcontractors)

- Shared risk and reward
- Multi-party contract
- Collaborative decision making and control
- Liability waivers among key participants
- Jointly developed and validated project goals

The most important theme of IPD is the blurring of lines between design and construction and among the traditional phases of design. Specially, IPD could enable the builders and suppliers to share their knowledge and expertise in the design phase.

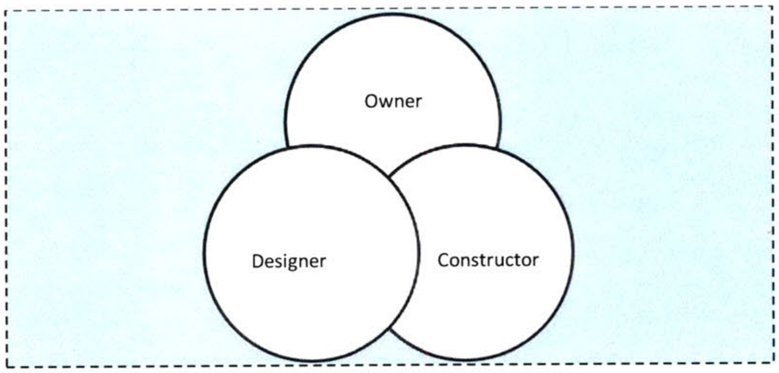


Figure 5.7: The relationship among participants under IPD model (adopted from AIA National and AIA California Council, 2007)

So far, IPD is still in its infancy, although its overall concept may represent a promising direction of project delivery approach in the future. To date, a limited number of projects have implemented the IPD model. More efforts are desired on improving the process to make it feasible to carry out in practice. But the framework of IPD makes it easier for the owner to bring flexibility into the project. First, in the design phases, the early involvement of key participants builds a platform for every party to contribute the flexibility design from different respective including economic, technical and operational level. Second, sharing risk and reward together reduces the total risk of the real options.

5.3 Owner-Local Authorities Contract

Real options built into the property at the beginning may be exercised in the future if necessary. Therefore, the whole project actually will be completed in more than one phase. Such phased development requires the property owner to form relevant contracts with the local relevant authorities to make secure the rights to carry out the later phases in the future (Figure 5.8). We discuss the contract between owner and local authorities regarding phased development in this section. Through four case studies of application of real options in real estate developments, Wittels and Pearson (2008) summarized the zoning, permitting, and building codes issues involved in building real options into properties specifically related to phased option.

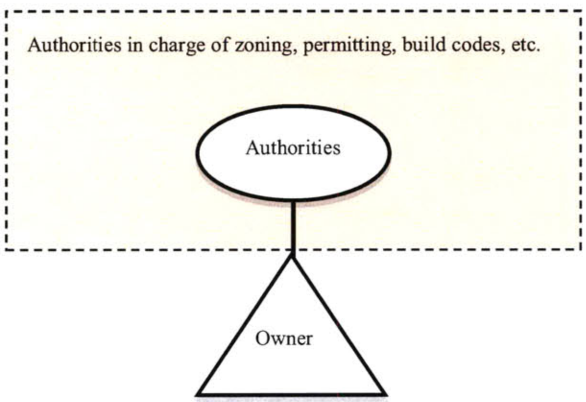


Figure 5.8: Owner – Local Authorities Contract

5.3.1 Zoning and Permitting

A significant uncertainty in planning a phased development is whether current zoning and permitting laws will still be in place at the time a subsequent phase is built. The risk of such an occurrence increases with the duration of time between phases, and probably cannot be eliminated entirely. Myriads of zoning, permitting, building code, and other laws at various governmental levels regulate the entitlement of projects, and it would be very difficult, if not impossible, to be able to lock in all such regulations at their current standard in perpetuity. The projects need to secure an adequate guarantee that the future phases could be built to give them sufficient comfort in moving forward.

Wittels and Pearson (2008) studies four projects that built flexibilities into the building. All porjects were able to lock in the zoning that applied to the site at the time of original construction to ensure that the vertical expansion could take place at the desired mass and height if and when the decision to move forward was made. All of the buildings of the case studies were able to lock in zoning through various mechanisms as agreed upon with the local municipality.

- Health Care Servie Corporation (HCSC) building: received a letter signed by the commissioner of the Chicago Department of Planning and Development ensuring that they would be able to expand vertically the building at any point in the future.
- Tufts University Dental School: Tufts submitted plans for a full 15 story building to the Boston Redevelopment Authority when it submitted the initial plans for the building.
- Court Square Two: the FAR of the site was increased from 2 to 15 when it was rezoned in 1986; the increase in FAR was contingent upon the owner of the site also paying for a subway station improvement.
- Bentall Five: Bentall Capital received permits that allowed it to construct the building in one or two phases. While no special accommodations were made to secure this, the developer felt that their reputation helped them to receive full permitting.

5.3.2 Building Codes

Possible changes in building codes have to be considered when planning a phased development. Even if a local municipality has guaranteed the right to develop a building, numerous changes in building and other codes from other government entities can take place over time that may make it difficult to proceed as originally planned.

For example, in one of Pearson and Wittels's case studies, HCSC was forced to adapt to a new Chicago code change after construction commenced on their vertical expansion: new codes require that cane jumps occur only when the initial phase was completed unoccupied which significantly narrowed the window during which such crane jumps can take place; wind codes and advancements in technology changed when HCSC was planning the vertical expansion which forced HCSC to alter the design of the structural system of the vertical completion phase.

5.4 Owner-Tenants Contract

In some instances, the project developer is not the final owner. Then, if the embedded real options require the project to be completed in several stages, the developer needs to form appropriate contracts with the potential tenants/stakeholders.

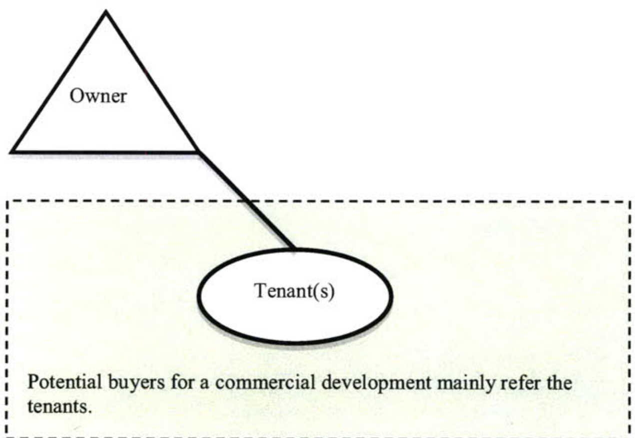


Figure 5.9: Owner – Tenants Contract

5.4.1 Contract with Tenants: Future Stages are Optional not Obligatory

In some countries/districts where staged development is common, authorities already realize the value of real options in infrastructure development and establish relevant regulations correspondingly. The Building Maintenance and Strata Management Act (BMSMA) established by the Building Construction Authority of Singapore is a good example (Urban Redevelopment Authority, 2004):

> "A staged development is a project that is built in a few stages instead of being built all at once. This allows the developer to change the types of development to be constructed in subsequent stages. For example, a developer may plan to build a block of residential apartments in the first stage and a block of offices in the second. Later,

> he may decide to change the block of offices to retail shops. He is allowed to do so provided such changes are disclosed to potential buyers in the staged development contract. This contract is the sale and purchase agreement signed between the developer and the purchaser. The stage development must be in prescribed form and accepted by the Commissioner of Buildings (COB)."

The Building Construction Authority requires developer to form "Staged Development Contract" with potential buyers, which should address the following aspects:

- The type of development – warranted development, authorized proposal or a combination of them. A warranted development is defined as one the developer warrants to the buyer will be constructed. If he does not, he can be compelled by law to carry it out; Authorized proposals refer to proposed developments that the developer is authorized to carry out but may not do so. If he does not he cannot be compelled by law to do so.
- Description of each development, for example, a block of the 20-storey apartment with a swimming pool in stage one and a block of 30-storey offices in stage two.
- Statutory covenants between the developer, subsidiary proprietor and mortgagee.
- The liability of the developer when he uses or maintains the common property that is completed in the earlier stages but used during the development of subsequent stages.
- By-laws, easement to be created or entered into the parcel.

When the property has more than one owner/stakeholder, the contract should also describe the how the share value evolves after future stages are completed. Here, share value is a figure that represents the proportionate share entitlement assigned to each strata unit in the same development and it is used to determine the amount of shares each owner has in relation to the other owners in the development. Changes in the types of development are likely to affect the share values that have been allotted earlier. Therefore, the staged development contract must state the range within which the share value could change. The contract should also spell out any provisions for adjustment in the event the range is exceeded.

5.4.2 Describe Distribution of Potential Benefit of Real Options in Contract

When the project under construction has multiple buyers/stakeholders, the project developer should describe clearly how the potential benefit of real options should be distributed among them. Usually, the biggest stakeholder of the property will still be the initial developer; otherwise, the developer will not have the incentive to design real options into the project during the design phase. To guarantee the right to exercise the real options in the future, the developer may need the support from the rest stakeholders if the developer alone is not able to make the decision. A fair benefit distribution approach creates the incentives for the rest of the stakeholders to support the developer's strategy, which should be clearly described in the contract between the two parties.

5.5 Safety Issue

There are many approaches to ensure the safety of earlier phases while the later phases are under construction.

- Take the case study of "Central" from Chapter 4 for example, the podium (from basement to L5) is shopping a center was completed as the first phase. The next floor (L6, the top floor of the podium) was designed for car parks and this is the second phase. So, when the tower (used as office) was under construction, people cannot access L6. L6 has a function of "separating".
- Metal Corridor: temporary metal corridors for pedestrian around certain construction area can ensure safety of the public outside the building.
- Sequence the construction work and provide separate construction access to separate the workers/material from the shoppers/pedestrian.
- Zoning the site: the working area is surrounded by safety apron.
- Control of Crane Jumps: the computer can control the jump of cranes. There are certain ranges for its jump angles and degree.
- Noise reduction by scheduling the work: the noisy piling work is completed before the occupation of the podium. And certain work will be done during non-office hours.

- Make use of podium roof: part of the podium roof designed as a roof garden will be used to locate the construction materials during the construction period of later stages.
- Protection Apron of the tower: Another widely used approach is put a protection net around the tower to catch the falling stuff.

CHAPTER 6: CONCLUSIONS AND FUTURE WORK

Through more three decades' development, real options analysis has already come into the main stream, both as a real asset valuation tool and a strategic decision-making method. Traditional valuation tools such as Net Present Value (NPV) ignore the value of flexibility while the real options approach recognizes the value of learning and is able to integrate flexibility into the valuation. This is important, because strategic decisions in long term infrastructure investment are rarely one-time events, particularly in investment-intensive industries. Real options analysis is by now recognized as a most appropriate valuation technique for corporate investment decisions because of its distinctive ability to take into account management's flexibility to adapt long term projects in response to uncertain technical and/or market conditions. In real estate development particularly, it has been applied to investigate various problems including development, re-development, abandonment of a property, lease contracts, and mortgage default and refinancing decisions, expansion of a property. To date, it has dramatically altered the way researcher model uncertainties in investment decisions.

However, real options analysis is not perfect just like any other comparable method. The trends and volatilities of uncertain factors are fundamental inputs for the valuation of real options, which are in many cases difficult to get meaningful estimates. Due to the changing patterns of the prices for the underlying assets, the estimates of their trend and volatility are highly sensitive to the span of time being considered. Current research on option valuation methodologies typically extracts estimates from data of a certain period (such as 10 years) without verifying that this period used is superior to others. Using the U.S. ands Singapore real estate markets as examples, this thesis investigates the sensitivity of price indices to the span of time considered. And this thesis suggests that sensitivity analysis should always be a key step of the valuation process and use Expected Option Value Interval (EOVI) to assist decision-making in real estate investment.

Option-thinking, especially proactive flexibility, is distinguished from their traditional counterparts above all by their response to uncertainty. The shift in outlook from "fear of uncertainty and minimize investment" to "seek gains from uncertainty and maximize learning" opens up a wider range of possible actions and is crucial to the usefulness of real options analysis as a strategic tool rather than a valuation model.

Since uncertainty is the key driver of option value, the study of uncertainty itself should always be at the core of flexibility design. An in-depth study of (a) both the feature/nature of each uncertainty (b) and interactions among between different uncertainties, inside and outside of the project/investment is essential and extremely important to give rise of attractive real options.

Although it is hard or even impossible to have an infrastructure designed "perfectly" today can still be "perfect" or up-to-date 20 or more years later, proactive flexibility enables the infrastructure to keep "updating" frequently. The initial design works as an open platform, on which later stages can built on using state-of-art technologies. The key here is what you build today should not becomes limitations of what you want to update tomorrow, but a supportive platform to appreciate future stages. Proactive flexibility gives rise to an infrastructure design that makes sense for both now and the future. This happens when the design use uncertainties, not the requirements from the user meeting, as one of the primary drivers of the design. It is extremely valuable to ensure a very consistent group of people are involved in a long-term infrastructure a long-term infrastructure design contains several phases. Because it ensures that members in the design team understand the concept behind the whole infrastructure and be on the same page.

A good thesis raises more good questions than it answers. Future work may consider the following issues:

- One possible direction of real options analysis in the future: migration of financial options application; Evolution inside real options itself, necessary support systems inside the organization. There are two important but neglected issues of ROA: On strategic level, real options analysis cannot be separated from the overall business strategies of the organization. On operational level, real options techniques cannot be treated as independent from other features of the organization.

- Also, address the effect of competition on options value and the close tie between competitive strategy and option-thinking for infrastructure investment. In the future, not only competition will shape real options analysis, option-thinking will also be widely applied on strategic level and thus shape future competitive strategies.
- Company/Organization-level framework: combine the industry-level framework of applying real options analysis with the specific situations of the company/organization to craft a framework that is able to be adopted by the company/organization. On this level, factors need to consider including, but not limited to, the management structure, the resources, the culture/style, overall strategy, competitive advantages. While the industry-level frameworks can be developed by the academia to ease the application of ROA in that industry as a whole, the company/organization level frameworks is really a burden of senior management of the company/organization themselves since they are the people who really know about their company/organization. Actually, the latter can also be done by hiring a management consulting company to assist this process.

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APPENDICES

Appendix A: Information of Option Valuation Models

Table A.1: Analogous Parameters in Financial and Real Option Models (Luehrman, 1998)

Financial option pricing model parameter	Analogous real options valuation model parameters	Sources of uncertainty
Stock price, S	Present value of expected cash flows from investment	Market demand for products and service, labor supply and cost, materials supply and cost
Exercise price, X	Present value of required investment costs in real assets	Availability, timing, and price of real assets to be purchased
Volatility (of stock price), σ	Volatility (of underlying cash flows)	Volatility in market demand, labor supply and cost, and materials supply and cost, correlation of model assumptions
Time to expiration of option, T	Period for which investment opportunity is available	Product life cycle, competitive advantage
Dividends	Cash flows lost to competitors	Product life cycle, competitive advantage
Risk-free interest rate, r	Risk-free interest rate	Inflation, market interest rates

Appendix B: Rent Forecasting Methodology

Table B.1: An Example of Office Rent Forecasting

	Inititive	Trend/yr	Vol/yr	Cycle	Current Noise
Mean	171.6	8.04%	25.6%		
Half-range (+/-)					15%
Period yrs full cyc				9	
Amplitude (pk - trgh)				0.5	
Phase yrs				0	
2009	171.6	171.6	171.6	171.6	171.6
2010	171.6	185.4	228.4	228.4	191.8
2011	171.6	200.3	314.3	367.6	397.0
2012	171.6	216.4	274.3	272.9	301.2
2013	171.6	233.8	316.1	333.2	410.4
2014	171.6	252.6	323.4	367.3	338.4
2015	171.6	272.9	396.2	368.5	391.2
2016	171.6	294.9	520.8	611.7	649.0
2017	171.6	318.6	672.2	554.1	683.7
2018	171.6	344.2	389.2	313.8	317.1
2019	171.6	371.8	453.0	557.9	548.0
2020	171.6	401.7	624.2	767.9	733.7
2021	171.6	434.0	629.9	774.2	716.3
2022	171.6	468.9	614.4	687.6	771.3
2023	171.6	506.6	731.9	553.6	530.3
2024	171.6	547.4	768.2	682.6	710.5
2025	171.6	591.4	925.9	925.4	943.9
2026	171.6	638.9	885.5	685.5	535.9
2027	171.6	690.3	617.7	701.9	639.9
2028	171.6	745.8	629.1	471.9	469.0
2029	171.6	805.8	746.1	636.9	660.7
2030	171.6	870.5	1039.5	1081.4	1141.4

Table B.2: An Example of Shop Rent Forecasting

	Initive	Trend/yr	Vol/yr	Cycle	Current Noise
Mean	122.1	2.60%	8.50%		
Half-range (+/-)					15%
Period yrs full cyc				7	
Amplitude (pk-trgh)				0.5	
Phase (yrs)				0	
2009	122.1	122.1	122.1	122.1	122.1
2010	122.1	125.3	122.6	122.6	153.1
2011	122.1	128.5	104.7	116.9	96.1
2012	122.1	131.9	100.2	125.3	127.6
2013	122.1	135.3	105.6	113.0	108.0
2014	122.1	138.8	116.5	89.2	79.8
2015	122.1	142.4	117.5	145.5	151.1
2016	122.1	146.1	127.2	154.4	148.1
2017	122.1	149.9	130.7	109.1	118.4
2018	122.1	153.8	135.6	162.8	134.9
2019	122.1	157.8	137.6	106.4	112.1
2020	122.1	161.9	139.0	104.2	125.2
2021	122.1	166.1	167.8	181.6	190.6
2022	122.1	170.5	158.1	159.7	130.6
2023	122.1	174.9	156.1	184.0	151.8
2024	122.1	179.4	171.7	135.5	142.4
2025	122.1	184.1	188.9	165.8	206.0
2026	122.1	188.9	153.6	192.0	180.1
2027	122.1	193.8	169.2	165.9	191.9
2028	122.1	198.8	164.9	206.0	244.2
2029	122.1	204.0	165.4	163.3	207.1
2030	122.1	209.3	166.9	138.9	106.9

The "half-range" is a parameter that is similar to the standard deviation, only for the triangular distribution instead of the normal distribution. The triangular distribution also does have a standard deviation, but the half-range may be easier to grasp concretely intuitively. A long-term history of commercial property prices can be useful to get some estimates of market trend, volatility, and cycle (including amplitude and period and perhaps even the phase - but always allow for a range of sensitivity around the historical parameters). The volatility should also have an additional component to reflect idiosyncratic risk (not included in the market volatility). This could be an independent accumulating random walk component additive to the market volatility, with a standard deviation of around 10%/year. Or we could just model the entire volatility (market + idiosyncratic) for a typical individual property as around 15% to 20% per year. Regarding the "noise" component (both initial and current), a typical standard deviation would be 10% to 15%. This noise component does not accumulate over time like the volatility does. Regarding the cap rate cycle, we could ignore that (use constant cap rate) if we are reflecting the entire cyclicality in the rent cycle. Or else we could ignore the rent cycle and apply the cyclicality through the cap rate, so as to give a cycle amplitude consistent with what we see in the historical data. Usually, +/- 30% or so, would equate in the cap rate to around +/- 200 basis-points (if ignoring the rent cycle) around. Which variable is more convenient to focus on will depend on what decision rule we want to employ for implementing flexibility. For some decision situations maybe we may want to separately model both rent and cap rate randomness.

Appendix C: Examples of Valuation of Three Scenarios

Table C.1: An Example of Valuation of Scenario 1

a) Rent and Lease-up Forecast

Rent & Lease-up Forecast										
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	1	2	3	4	5	6	7	8	9	10
Shop Rental (S$ per sqm per year)	1072.6	1155.8	763.1	784.7	1410.6	879.3	1025.3	1623.1	935.3	1368.3
Office Rental (S$ per sqm per year)	1163.1	1899.8	2265.4	1337.9	1396.0	2592.5	2752.7	2207.5	3043.8	2519.3
Office cumulative Lease-up			44.1%	58.6%	73.2%	74.5%	80.5%	84.7%	90.1%	93.6%
lease-up as % of scenaro 1			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	11	12	13	14	15	16	17	18	19	20	21
Shop Rental (S$ per sqm per year)	1321.6	1756.4	1417.9	1192.2	1840.8	1407.3	1447.2	2407.5	1710.5	2103.8	1940.7
Office Rental (S$ per sqm per year)	5015.7	7499.5	12298.7	8737.9	11841.2	13829.6	10997.6	15537.0	14708.6	19333.7	23344.8
Office cumulative Lease-up	93.8%	94.1%	96.2%	97.5%	98.4%	98.6%	99.1%	99.4%	99.6%	99.8%	99.8%
lease-up as % of scenaro 1	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

b) NPV Calculation

NPV Calculation													
Year	Beginning of 2010	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	0	1	2	3	4	5	6	7	8	9	10	11	12
Development Costs (S$ million)	340.8	65.3	33.7										
Rental Income (S$ million)		0.0	0.0	42.6	31.4	43.8	48.8	53.5	57.9	55.5	57.0	87.4	126.5
Operating Costs (S$ million)		0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Income Before Income Taxes (S$ million)	-340.8	-65.3	-33.7	42.2	31.1	43.5	48.5	53.2	57.6	55.2	56.7	87.0	126.2
Tax Shields from Debt Finance													
Discounted Cash Flows (S$ million)	-340.8	-59.9	-28.4	32.6	22.0	28.2	28.9	29.1	28.9	25.4	24.0	33.7	44.9
NPV (S$ million)	210.0												

2022	2023	2024	2025	2026	2027	2028	2029	2030
13	14	15	16	17	18	19	20	21
180.2	131.5	182.4	199.1	164.5	239.1	215.8	39.3	36.2
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
179.9	131.2	182.0	198.8	164.2	238.8	215.5	39.1	36.0
58.7	39.2	50.0	50.1	37.9	50.6	41.9	7.0	5.9

TableC.2: An Example of Valuation of Scenario 2

a) Rent and Lease-up Forecast

Rent & Lease-up Forecast											
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	1	2	3	4	5	6	7	8	9	10	11
Shop Rental (S$ per sqm per year)	1072.6	1155.8	763.1	784.7	1410.6	879.3	1025.3	1623.1	935.3	1368.3	1321.6
Office Rental (S$ per sqm per year)	1163.1	1899.8	2265.4	1337.9	1396.0	2592.5	2752.7	2207.5	3043.8	2519.3	5015.7
Office Cumulative Lease-up			44.1%	58.6%	73.2%	74.5%	80.5%	84.7%	90.1%	93.6%	
Lease-up as % of scenario 2			44.1%	58.6%	73.2%	74.5%	80.5%	84.7%	90.1%	93.6%	93.8%

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
12	13	14	15	16	17	18	19	20	21
1756.403	1417.93	1192.159	1840.763	1407.342	1447.221	2407.515	1710.5323	2103.838	1940.743
7499.502	12298.7	8737.877	11841.2	13829.57	10997.6	15537.01	14708.56	19333.69	23344.84
94.1%	96.2%	97.5%	98.4%	98.6%	99.1%	99.4%	99.6%	99.8%	99.8%
94.1%	96.2%	97.5%	98.4%	98.6%	99.1%	99.4%	99.6%	99.8%	99.8%

b) NPV Calculation

NPV Calculation												
Year	Beginning of 2010	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	0	1	2	3	4	5	6	7	8	9	10	11
Development Costs (S$ million)	341	65.3	33.7	71.0								
Rental Income (S$ million)		0.0	0.0	35.0	51.9	68.4	98.5	111.9	107.5	124.2	114.1	205.0
Operating Costs (S$ million)		0.0	0.0	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Income Before Income Taxes (S$ million)	-341	-65.3	-33.7	-36.3	51.4	67.9	98.0	111.3	107.0	123.7	113.6	204.4
Tax Shields from Debt Finance												
Discounted Cash Flows (S$ million)	-340.8	-59.9	-28.4	-28.1	36.4	44.1	58.5	60.9	53.7	57.0	48.0	79.2
NPV (S$ million)	972.6											

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	12	13	14	15	16	17	18	19	20	21
Development Costs (S$ million)										
Rental Income (S$ million)	306.17	478.83	344.40	473.07	540.27	436.60	624.35	580.69	39.26	36.22
Operating Costs (S$ million)	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.19	0.19
Income Before Income Taxes (S$ million)	305.62	478.27	343.85	472.51	539.71	436.04	623.79	580.13	39.08	36.03
Tax Shields from Debt Finance										
Discounted Cash Flows (S$ million)	108.66	156.00	102.89	129.72	135.94	100.76	132.24	112.83	6.97	5.90

TableC.3: An Example of Valuation of Scenario 3

a) Rent and Lease-up Forecast

Rent & Lease-up Forecast											
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	1	2	3	4	5	6	7	8	9	10	11
Shop Rental (S$ per sqm per year)	1072.6	1155.8	763.1	784.7	1410.6	879.3	1025.3	1623.1	935.3	1368.3	1321.6
Office Rental (S$ per sqm per year)	1163.1	1899.8	2265.4	1337.9	1396.0	2592.5	2752.7	2207.5	3043.8	2519.3	5015.7
Cumulative total lease-up (% of total)			44.1%	58.6%	73.2%	74.5%	80.5%	84.7%	90.1%	93.6%	93.8%
% of office space in Scenario 1 leaseed up			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
% of flexible space pre-lease up			17.6%	39.0%	60.4%	62.4%	71.3%	77.5%	85.4%	90.5%	90.9%

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1756.4	1417.9	1192.2	1840.8	1407.3	1447.2	2407.5	1710.5	2103.8	1940.7
7499.5	12298.7	8737.9	11841.2	13829.6	10997.6	15537.0	14708.6	19333.7	23344.8
94.1%	96.2%	97.5%	98.4%	98.6%	99.1%	99.4%	99.6%	99.8%	99.8%
100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
91.3%	94.3%	96.3%	97.6%	98.0%	98.7%	99.1%	99.4%	99.6%	99.7%

b) Decision Rule

Decision Rule												
Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
		1	2	3	4	5	6	7	8	9	10	11
Annual Office Rental Growth Rate			38.8%	16.1%	-69.3%	4.2%	46.2%	5.8%	-24.7%	27.5%	-20.8%	49.8%
% of flexible space pre-lease up		17.6%	39.0%	60.4%	62.4%	71.3%	77.5%	85.4%	90.5%	90.9%	91.3%	94.3%
Hurdle Rate for Rental Growth	5%											
Hurdle Rate for Pre-lease up	70%											
Excersice Option or Not		No	No	No	No	No	Yes	Yes	No	Yes	No	Yes
"Yes" Count		0	0	0	0	0	1	1	0	1	0	1
Cumulative "Yes" Count	0	0	0	0	0	0	1	2	2	3	3	4

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
12	13	14	15	16	17	18	19	20	21
33.1%	39.0%	-40.8%	26.2%	14.4%	-25.8%	29.2%	-5.6%	23.9%	17.2%
96.3%	97.6%	98.0%	98.7%	99.1%	99.4%	99.6%	99.7%	0.0%	0.0%
Yes	Yes	No	Yes	Yes	No	Yes	No	No	No
1	1	0	1	1	0	1	0	0	0
5	6	6	7	8	7	7	7	6	6

c) NPV Calculation

NPV Calculation												
Year	Beginning of 2010	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	0	1	2	3	4	5	6	7	8	9	10	11
Podium+SOHO1+SOHO2 (Senario 1)												
Development Costs	340.8	65.3	33.7									
Rental Income		0.0	0.0	42.6	31.4	43.8	48.8	53.5	57.9	55.5	57.0	87.4
Operating Costs		0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
CFs Before Income Tax	-340.8	-65.3	-33.7	42.2	31.1	43.5	48.5	53.2	57.6	55.2	56.7	87.0
Studio Office+Regular Office												
Development Costs (S$ M)		0.0	0.0	0.0	0.0	0.0	73.2	0.0	0.0	0.0	0.0	0.0
Rental Income (S$ M)		0.0	0.0	0.0	0.0	0.0	0.0	58.5	49.7	68.9	57.2	117.8
Operating Costs (S$ M)		0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2
CFs Before Income Tax (S$ M)		0.0	0.0	0.0	0.0	0.0	-73.2	58.3	49.5	68.6	57.0	117.5
Scenario 1 + Vertical Expansion	-340.8	-65.3	-33.7	42.2	31.1	43.5	-24.7	111.5	107.1	123.8	113.7	204.6
Discounted CFs (S$ million)	-340.8	-59.9	-28.4	32.6	22.0	28.2	-14.7	61.0	53.7	57.0	48.0	79.3
NPV (S$ M)	930.2											

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
12	13	14	15	16	17	18	19	20	21
126.5	180.2	131.5	182.4	199.1	164.5	239.1	215.8	39.3	36.2
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
126.2	179.9	131.2	182.0	198.8	164.2	238.8	215.5	39.1	36.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
179.8	298.8	213.0	290.8	341.2	272.2	385.2	364.9	0.0	0.0
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0
179.5	298.5	212.8	290.5	341.0	271.9	385.0	364.7	0.0	0.0
305.7	478.4	343.9	472.6	539.8	436.1	623.8	580.1	39.1	36.0
108.7	156.0	102.9	129.7	136.0	100.8	132.2	112.8	7.0	5.9